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Editorial Announcement

For a number of years the trustees of the American Medical Association have purposed the establishment of an ARCHIVES OF SURGERY similar in character and scope to the *Archives of Internal Medicine*, the *American Journal of Diseases of Children*, the *Archives of Neurology and Psychiatry*, and other comparable publications. Delays of various kinds have arisen, among others those resulting from the war, which have prevented the fulfilment of this purpose. The fact, too, that there were already in this country two great journals of surgery, the *Annals of Surgery*, and *Surgery, Gynecology and Obstetrics*, has made this delay of less consequence.

The Journal of the American Medical Association has the largest circulation of any medical journal in the world, and represents the activities of the American medical profession. *The Journal*, therefore, must carry contributions which will cover all the different fields of medicine. Contributions to its surgical section are so numerous as to make it difficult to publish them all in *The Journal*, especially since many of these contributions are too technical to be of interest to the entire profession.

The Trustees in establishing the ARCHIVES OF SURGERY have wisely determined that it shall not enter into competition with the journals of surgery now in existence. They believe that it should, besides lessening the burden of *The Journal's* publication, establish a sphere of its own. They believe, and again rightly, that another journal of clinical surgery is not warranted, and the task of the editor, Dr. Dean Lewis, and of the editorial board is to develop an organ which will in no way interfere with the justly earned successes of the existing publications, and yet establish a journal which will be creditable to the great organization that it represents, and sufficiently useful to the profession to warrant its entering the field.

In the growing period of surgery, it was not possible to train surgeons in the true sense. Only a few men had the opportunity to work as assistants to experienced surgeons. This is no longer the case. In the future, the surgeon will serve an apprenticeship, and three-year courses of instruction in which such training can be given are now being offered for those graduates in medicine who have served their hospital internship. It is the hope of the editorial board that the ARCHIVES OF SURGERY may be one of the organs of expression in this growing field of surgical education, and that it may furnish an opportunity for the publication of original articles pertaining to

research and investigation in those subjects which lay the foundation for sound surgical progress. American surgery has developed unevenly. Many competent observers are of the opinion that clinical and operative surgery and surgical technique have advanced faster than the growth of knowledge with regard to the fundamental but less attractive branches would warrant. It may be said that the philosophy of surgery has lagged, and operations based on unsupported opinions as to their wisdom or their necessity are too frequently advocated.

The ARCHIVALS OF SURGERY will attempt at least to enlarge the surgical horizon and assist in establishing surgery on a sounder basis. Unpleasant as it may be, the editors will not hesitate to comment editorially on the papers published in its columns in order that both sides of a moot question may be considered. The reader will be given an opportunity to peruse surgical fads and fancies if such be presented, but if the subject matter introduces questionable material it will not be allowed to go unchallenged.

I wish, at this time, to express my indebtedness to the *Annals of Surgery* and to *Surgery, Gynecology and Obstetrics*, and especially to their distinguished editors. The scientific pages of the *Annals* have ever been to me a source of surgical wisdom and inspiration. *Surgery, Gynecology and Obstetrics*, combined with its abstract department, is one of the most extraordinary achievements in the history of surgery. Its editor, by his vision, knowledge and courage, has placed the surgical profession in his debt.

WILLIAM J. MAYO

ARCHIVES OF SURGERY

VOL 1

JULY, 1920

No 1

TWO CASES OF SPLENECTOMY FOR SPLENIC ANEMIA

A CLINICAL LECTURE, JAN 21, 1920, TO THIRD YEAR STUDENTS, TELLING
AN OLD STORY

HARVEY CUSHING, M D

Professor of Surgery, Medical School of Harvard University

BOSTON

AND

A REPORT ON THE PATHOLOGIC CHANGES IN SPLENIC ANEMIA

(Written in 1900, but not Published)

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Baxley Professor of Pathology, Johns Hopkins University Medical Department

BALTIMORE

Gentlemen —We went over together last week some patients with biliary disorders showing degrees of jaundice. One of them — Mary Jones, as you will recall — had a history of frequently recurring attacks of cholelithiasis over a period of nine years, but had never before been jaundiced. As her jaundice was rapidly fading, we arrived together at the conclusion that the common duct would be found free.

You saw the patient operated on subsequently by the resident, Dr Cutler, and will remember that at an early stage of the procedure digital palpation led him to believe that there must be a stone in the common duct. After removing the gall-bladder, which was full of stones, he found that the impression of a deeper stone had been given to the finger by a pancreatic nodule which partly enveloped the lower portion of the duct.

It is well for you to bear in mind that this is not an uncommon observation, though less common now, I am sure, than in former days before it was pointed out — first by Mayo Robson, I believe — that chronic pancreatitis was a common accompaniment of cholelithiasis and often produced a degree of induration frequently mistaken on palpation, particularly through the inadequate openings then made, for malignant disease or for a large common duct stone.

Now, Mr B——, will you tell me what you notice about this patient, named Alvin Landers, whom we may uncover for your inspection?

Third-Year Student — "He appears to be jaundiced, but in his inguinal region there is a newly healed wound which suggests an operation "

Yes, he has a yellowish tint to his skin apparent also in his conjunctivae, quite unlike the color, as you will recall, of the gallstone cases you saw a week ago. But do you think this incision could have any relation to the skin discoloration, and, if not, what does it suggest to you?

Student — "It looks like a recent hernia incision "

It is, I believe, and we will now hear the essential facts of his clinical story from Mr A——

Fourth-Year Student (clinical clerk) — "The patient is 35 years of age, a restaurant keeper, who entered the hospital January 1. He tells of having a small 'lump' in the right groin for five years, which gradually increased in size, and he has worn a truss for three years. The evening before admission, while straining at stool, the 'lump' suddenly enlarged and could not be reduced. Vomiting set in during the night, a physician was called, but he was unable to reduce the hernia and so sent him to the hospital the next morning. A diagnosis of strangulated indirect inguinal hernia was made. The hernia was immediately operated on under local anesthesia, and though the bowel was much discolored, the vessels were not thrombosed, and sufficiently good circulation returned into it to justify its replacement.

"On admission it was noticed that he was jaundiced, and it was learned that this condition had been present for fifteen years, ever since an attack of pain in the right upper quadrant, accompanied by nausea and vomiting which confined him to bed for six months. He states that during that illness he had dark-colored urine and clay-colored stools, and that he subsequently passed over 200 gallstones, but refused a proposed operation because of his mother's objections, for she is said to be even more yellow than he, and has had jaundice herself for many years and has done well without operation."

Now, Mr B——, before we go into this story any further, what impression have you perhaps gained regarding this patient?

Third-Year Student — "I think he must have some other trouble than the rupture for which he came to the hospital."

Yes, undoubtedly he has, although, as you have doubtless been told before this, it is the safest plan to attribute the symptoms which a patient presents to one underlying cause—a symptom complex—rather than to look for multiple causes. But here the conditions are somewhat different—an exception which proves the rule—for we have an acute complication on the part of an old rupture in a patient with some underlying trouble, and what do you think it may be?

Third-Year Student —“It is very peculiar that he should have had such persistent jaundice if due to gallstones, and also that his mother has gallstones and jaundice ”

It is peculiar, and, what is more, as Mr A—— could tell us, we have since learned that he also has a brother who has chronic jaundice. Then, too, you have noted that his jaundice has a curious lemon-yellow tint, and, what is more, he has no evidence of bile in his urine, nor are his stools pale in color. Is it not the usual thing in cases of icterus to find bile in all the body fluids?

Student —“I think so ”

Yes, in all the body fluids except the cerebrospinal fluid, for, as I have told you, the choroid plexus, unless diseased or injured, is a filter so effective as to prevent the passage from the blood of all but a very few chemical substances. But here, with exception possibly of the blood, the fluids are not stained, not even the urine, and it is therefore what is called an acholuric jaundice. Now I may be trespassing on a subject you have not as yet covered and would like to ask the class whether they have any idea what may be wrong with this man in view of his history, and will ask those to raise their hands who know what we are likely to find on palpation of the abdomen. (Many of the class responded.) Some of you, at least, appear to have met with this condition in your medical lectures, and so, Mr B——, will you let us know what you feel in this patient's belly?

Third-Year Student —“He has a large mass on the left side which descends with respiration and I think must be his spleen. It reaches the level of the navel ”

Yes, and what would you like to know next?

Third-Year Student —“The findings in his blood ”

Clinical Clerk —“The blood shows 2,800,000 reds, 11,000 whites, and 60 per cent hemoglobin. The differential is not remarkable — 67 per cent polymorphonuclears, 25 per cent lymphocytes, and 20 per cent eosinophils. The red cells do not show any departure from normal, but the fragility test made by Dr Kebajian shows beginning hemolysis at 0.75 per cent, as against 0.46 per cent for the control ”

What, then, might be your diagnosis in this case, Mr B——?

Third-Year Student —“Hemolytic jaundice, probably of the congenital type ”

And would you advise any treatment for the condition?

Third-Year Student —“We have been told by Dr M—— that splenectomy is of great benefit in these cases ”

Yes, I think that is the prevailing idea, particularly regarding this family variety of splenomegaly. It is the type to which attention was first directed, I believe, by the students of Minkowski, of Chauffard

and of Vaquez, and it has been variously called congenital (or familial) hemolytic jaundice (or icterus), as you will

I do not know what others have told you, but I do not believe that it is at all clear whether the underlying fault in these conditions lies with the blood or with the spleen, or possibly elsewhere. The fact that symptomatic improvement has followed splenectomy speaks in favor of a splenic origin, others ascribe the disorder to a primary change in the blood, to the low osmotic resistance of the erythrocytes, or possibly to an imperfect blood formation or to some form of hemolysis of normal corpuscles due to an unknown chemical influence. This is a little vague, perhaps, but then, vagueness still characterizes our knowledge of blood-forming organs. Certainly, if the disease is hereditary it probably obeys Mendelian laws, and therefore should be much more common in affected families than the presence of icterus and splenomegaly would indicate, so that we may assume there are many milder cases unrecognized having neither jaundice nor large spleens. In short, the disease may possibly exist in the absence of the two outstanding symptoms which gave it its name. Nor is this unique.

Then, too, authorities are still equally indefinite in regard to the cause of the jaundice in the absence of cirrhosis or obstruction of the bile passages. Some ascribe it to the clogging of the biliary capillaries by an excess of viscid and highly pigmented bile, a consequence of blood destruction. On this I cannot pass.

This whole subject is one in which I am at this moment more interested from the standpoint of your fellow student than from that of a teacher, and as I have refreshed my mind regarding it before coming to this exercise, I will show you, for your benefit, the volumes I consulted. Here is a book you will find very useful, particularly because of its brevity of description and valuable bibliography. It is Barker's *Clinical Diagnosis of Internal Diseases*, and in this second volume there are a few pages devoted to the diseases of the spleen, where you can get your essential facts, up to 1916, very quickly and very briefly. You are given also, some of the more important references—in the author's estimation at least—so that you may run our prevailing ideas down to their source of origin. Such a treatise as this can serve you as a short cut to the *Index Catalogue* and *Index Medicus*, where, at your stage, you are likely to be swamped by the immense number of titles on a given subject.

But possibly this volume should have come first—the last edition of Osler's *Principles and Practice*, and, as I have told you before, it is perhaps the best jumping-off place for most subjects, whether surgical or medical, that you may wish to look up. You will find here under "Jaundice" a note about the hemolytic varieties, and the fact

that it was Chauviard who first pointed out the increased fragility of the red corpuscles — a note also on a hereditary form of icterus in infants, first described by Glaister as well as this acholuric form before us which Minkowski reported. However, Osler does not feel that the disease is necessarily familial, though some writers have attempted to subdivide the cases into acquired and inherited types.

And there is another thing I may call to your attention which I had forgotten — namely, that in the icterus of the new-born, in contradistinction to other forms, the central nervous axis may be bile-stained, though I do not know whether this is also true of the cerebrospinal fluid in these cases, contrary to what I have told you.

Let us now turn to the section on the spleen, in the diseases of which Dr. Osler became interested, and to which he made important clinical contributions. Here you will find in the section on "Primary Splenomegaly with Anemia" a description of splenic anemia or Banti's disease, which he defines as "a primary disease of the spleen of unknown origin characterized by progressive enlargement, attacks of anemia, a tendency to hemorrhage, and in some cases a secondary cirrhosis of the liver with jaundice and ascites," and please observe that he says further, "The spleen itself is the seat of the disease, as is shown by the fact that complete recovery follows its removal."

You will note that the jaundice shown by Alvin Landers here has been an early and not a late symptom of his malady, and that there are no evidences of hepatic cirrhosis, nor have there been hemorrhages. Otherwise this brief description might cover the case of our patient well enough.

Osler, as you see, laid great emphasis on the tendency to hemorrhage, particularly hematemesis, as a special feature of Banti's disease, with recurring attacks often over many years, and he points out that the diagnosis of ulcer of the stomach may consequently be made. As I shall return to this again, I may read that "the bleeding may be of great severity. On several occasions one of my patients was brought into the hospital completely exsanguine, in two the hemorrhage proved directly fatal, in a third the hemorrhage proved fatal ten days after a successful removal of the spleen. One patient had splenomegaly with repeated hemorrhages, and has now (1912) had more than twelve years of good health after splenectomy."

Again, under "Hemorrhage from the Stomach," Osler gives as causes passive congestion and splenomegaly, for he says (page 507) that "gastrorrhagia is by no means an uncommon symptom in enlarged spleen, and is explained by the intimate relations which exist between the vasa brevia and the splenic circulation." I quote this because the source of hemorrhage in these cases is another matter to which we will return.

Now let us go a little farther and turn to one of the systems of medicine which you will find in the school library if you do not happen to have succumbed yourself to a sales agent. Having already spoken of Osler's relation to the subject, you may turn to Modern Medicine or to Allbutt and Rolleston's System, in which there is also an exceedingly good chapter on diseases of the spleen, where you will find a still more elaborate presentation of the topic.

And lastly, to pursue the subject still farther without going to original sources, we may turn to some work of monographic form, and the most recent that I know of in English is this volume by Pearce, Krumbhaar and Frazier, on the spleen and anemia, which Dr. Cutler has loaned to me, so that here again, and proportionately in still greater detail, you will find this general topic gone into.

Thus in looking up a subject one proceeds, from a brief synopsis, to a textbook, to such short monographs as occur in standard system of medicine, to separately printed and larger monographs, and as a last court of appeal to the general literature of our journals through the agency of our great indices, and the results of so doing once on a time, fill this filing box as I shall tell you later, for twenty years ago, I would have had less need of consulting recent literature before coming to an exercise on this subject.

At that time this case would probably have been called primary splenomegaly or splenic anemia, or possibly splenic anemia with icterus, in view of this additional symptom, but of late years various types of splenomegaly with varying forms of anemia have come to be separated off, for one reason or another, from the cases which, in 1900, would probably have been grouped together — and may come to be again.

One might give a historical résumé of this process of separation somewhat as follows:

At first when we knew far less even than now of splenic function, enlargements of the organ were of course well recognized. They, for the most part, were secondary manifestations of some known disease process. Thus, we may dismiss, in our present consideration, the acute splenomegalies of various febrile states, the large spleen of chronic malaria and kala-azar, of syphilis, tuberculosis and echinococcus, the enlargement due to venous stasis of cardiac or hepatic origin.

A second step, and a most important one, was the recognition by Virchow and others of a splenic enlargement associated with a leukemia.

A third chapter would properly record the recognition of cases not due to the ordinary causes given above nor associated with an increase of white cells in the blood and therefore called "pseudoleukemias" by Cohnheim.

Then as a *fourth step* came Banti's first monograph in 1883, describing splenic anemia which was withdrawn from the nonleukemic splenomegalies, and at about the same time in France came Bruhl's papers on splenomegalie primitive. Both Banti and Bruhl, doubtless provisionally, included numerous allied disorders, and Banti, in the belief that the spleen was the seat of the disease, advocated its removal.

As a *fifth step*, Gaucher separated off from splenic anemia of the Banti type a form with a peculiar histologic picture, characterized by masses of endothelial cells in the spleen and by hypertrophy of the liver. At about the same time —

A *sixth step* — a side step possibly — was taken by von Jaksch, who gave the name pseudoleukemia infantum to a form of splenic anemia which had been recognized in infants even before his time.

And then, finally, this disease, hemolytic jaundice, was separated off, and some are attempting to split this up into acquired (Hyem-Widal) and familial (Minkowski-Chauffard) types. This is the sort of thing that usually happens, and we are probably not through yet with these clinical distinctions, though probably many of them have much in common, and if Banti disclaims this progeny for splenic anemia, they at least were hatched in the same pseudoleukemic nest.

Now I wish to approach from a different angle these conditions of splenomegaly with anemia, in the surgical aspects of which I was once greatly interested.

STUDIES FROM OLD CASE-BOOKS

I shall take advantage of the occasion to speak to you of the value of case records and why it is we put the names of these patients on the board, and keep referring to them, because as I told you early in your year I wanted you to remember each of these clinical cases that you see, as patients, rather than merely as examples of some given symptom, such for example as jaundice in this man who has just gone out.

I have brought in here, to show you, a volume entitled "Studies of Old Case-Books," by Sir James Paget, whose life I hope all of you will some day read. The book contains accounts of some odd cases and conditions, with chapter headings such as "Diabetic Gangrene," "Ununited Fractures in Children," "Use of Will for Health," and so on, but what I want to quote are some paragraphs from his preface. He says

Few things of the kind seem to be more useless than old case-books. To the writer himself they may have some value and even great personal interest; he may profitably study himself in them as well as some of the facts which he has recorded.

Then he goes on to say

Thus as one looks through volume after volume, they seem to prove nothing but a waste of time, till one reflects that the present use of old case-books is no just estimate of their value in past years. For, to say nothing of the materials they may have supplied for work already done in lectures or in books and papers published at various times, they were among the very best means of self-education. The habit of recording facts is nearly essential to the habit of accurately observing and remembering them. That which we intend to record we are bound and may be induced to observe carefully, and the very act of carefully recording is nearly equivalent to a renewed observation. Thinking of this and of their personal interest to myself, I ought, perhaps, to have been content with the good service that my case-books have rendered to me and with the hope that they have been, in some measure, indirectly useful to others.

Now your attention has been called to this old volume of Paget's, because I wish to show you the accumulations which I have here of two old case reports concerning which I have much the same feeling that he has expressed in the quotation I have read to you. I show them to you also because I want you to learn to accumulate facts and material for yourselves through what you may learn in your various clinics and in your use of the journals in the library which I have so often urged you to get in the habit of going over. If you do nothing more than to jot down references to these articles, to which I have called your attention, and to put them with the notes which you must have already taken down about splenic diseases, together with one or two case reports of patients that may have been shown to you, like Alvin Landers this morning, and if you will keep this little collection of your own up to date by occasional additions from what you run across in your reading, you will build up a textbook of your own—one very much better than anything you can buy bound in covers, which must necessarily quickly become antiquated. By this means, when the time comes to need them, you will be able to recall your facts infinitely better than in any other way.

This old filing box which, until this morning, had certainly not been opened since 1910, is labeled "Spleen," and it represents some ancient accumulations regarding this topic which is under consideration, and I will tell you the story.

There came to the Johns Hopkins Hospital, March 9, 1898, a man, aged 33, C D B by name, a farmer from Fincastle, Va., complaining of dyspepsia, and hemorrhages from the stomach and bowels. These he had had for nine years, the loss of blood at times having been sudden and very profuse, the attacks coming possibly once every twelve months. I remember him as a little fellow with a curious brownish coloration of the skin and a big spleen which was taken to

be an ague-cake doubtless in view of his place of domicile. He had a marked anemia, with hemoglobin of 25 per cent, about 3,000,000 reds, and a leukopenia of 2,800 cells. His gastric examination (this was before the days of bismuth roentgen-ray studies you will observe) showed a slightly dilated stomach with visible peristalsis, and a test meal showed a considerable hyperacidity. He was discharged, and returned to the hospital again on October 26, with his blood picture somewhat improved. A presumptive diagnosis had been made of bleeding peptic ulcer and he was transferred to the surgical service for operation.

Being the resident surgeon at the time, the case fell to my lot, but it was just at this period, as I remember it, that the first edition of Allbutt's System was published. I had invested in a set of the volumes and by chance had read Samuel West's article in Vol V, p 539, on splenic anemia. The condition seemed to fit the case of this man so exactly that I remember going over to Dr Osler's house with some needless trepidation, the evening of the patient's transfer, to ask him if he did not think it was possibly a case of splenic anemia, and if I found no sign of pyloric ulcer would he mind letting me take out the man's spleen, because there had been one or two promising cases referred to by West. As was characteristic of him under such circumstances, he said, "Go ahead, young man, and do what you think best."

So the next day I made a primary exploration on the right side, found nothing, and then proceeded through a new incision to take out his spleen. It was very adherent, and I had a good deal of difficulty from bleeding during the separation of the adhesions under the diaphragm, but, nevertheless, in spite of his anemia, he recovered.¹

There is a tradition, as you know, in most clinics, that when rare conditions turn up they often come in pairs, and while this Mr C D B was still in hospital, another patient, Mr W H, 30 years of age, was admitted to Dr Osler's wards² with a very similar history—a large spleen extending to the umbilicus and several attacks of profuse hematemesis occurring over an eleven-year period. The blood picture was very much the same, there was the same muddy brownish tint to the skin, and he complained similarly of some upper abdominal soreness.

¹ The case was subsequently referred to in all of Osler's three papers (1) "On Splenic Anemia," *Am J M Sc*, January, 1900, Case IV, (2) "Chronic Splenic Enlargement with Recurrent Gastro-Intestinal Hemorrhages," *Edinburgh M J*, May, 1899, p 447, Case II, (3) "Anemia Splenica," *Tr Assn Am Physicians*, 1902, Case IV.

² Osler refers to him as Mr A B in his first paper, Case V, second paper, Case III, and third paper (after operation) Case V.

This man also was operated on, and in addition to the large spleen there was found some ascites and a slightly cirrhotic liver. The same surgical difficulties were encountered from dense adhesions due to a perisplenitis, and I well remember his being kept in the operating room inverted on the table until the following day, as it seemed unsafe to move him.

He made an excellent operative recovery and his wound healed, but on the tenth day he had a sudden profuse vomiting of dark blood, fully 2 liters or more in amount, and died almost before the attendants could reach his bedside. At autopsy it was found that the bleeding had come from an esophageal varix, and I pass around this very beautiful water-color made by Mr. August Horne, one of the artists then in Dr. Kelly's clinic, which shows the lesion.

So far as I have been able to determine this morning in looking over these accounts of splenic anemia, Dr. Osler in particular laid stress on hematemesis, and his impression was doubtless colored by these early cases. So far as I am aware, also, this was the first and perhaps the only case in which the bleeding was shown to come from an esophageal varix, for I have read you the note in Osler's Practice in which he ascribes the hematemesis to capillary hemorrhages from the stomach. Esophageal varices of course are common enough and may occasionally be a source of fatal hemorrhage in extreme passive congestion either of cardiac or hepatic origin. In both of these patients, however, that I have referred to, the changes in the liver were insignificant, at least in gross appearances, for though in Banti's disease proper there is a terminal stage of cirrhosis with ascites, this was not apparent in Case I, and but very slightly in evidence in Case II. Disease of the portal vessels, irrespective of stasis, was a feature of the disease Banti called attention to, and it may have some bearing on this symptom of recurrent bleeding.

Now let us return to this box, not only that I may show you what these accumulations are, but that I may tell you the end-results of the story of our friend from Fincastle. I do so particularly because I want to warn you as well as my junior surgical colleagues here lest there be too great enthusiasm over splenectomies for these obscure diseases.

I am led the more to do so because Mr. B—— has told us that in this patient we have just seen, splenectomy is the proper procedure, but I am not at all sure but that the boy's mother is correct in believing that she has lived as long with her hemolytic jaundice as she would have done if her spleen had been removed. I find that in the hospital records here there have been seven cases of splenectomy for the following conditions: splenic anemia, 1, splenomegaly, 2, pernicious anemia, 2, fever, cause unknown, 1, and chronic splenitis, 1, not a



Water color sketch by August Horne of the esophageal varices with rupture leading to fatal hemorrhage in the second case.

very large series, and I will show you two recent articles on the subject, one of them from the Mayo Clinic, where possibly the largest experience has been had with these particular operations

Unless the spleen is very adherent and very large and unless the patient is unduly anemic and in poor health, its removal is not an operation of exceptional magnitude, and unquestionably when we are reaching out for some therapeutic measure in regard to a possible cure of an obscure disease the temptation is strong to remove an organ which evidently participates in the disease, if it is removable, even though it may not be the primary source of the disorder. We must not, however, be misled under the circumstances by mere operative recoveries into the belief that the patient has necessarily been benefited — benefited in the way that Alvin Landers has been by his hernia operation, which you will recognize as having been an urgent and possibly life-saving procedure

I feel a little conscious-smitten when I find that the case of Mr C D B — has gotten into the literature as one of the early recoveries and possible cures of Banti's disease by removal of the spleen — particularly as *two cases*. For here is a much-quoted article by Gaston Torrance, on "Splenectomy in Banti's Disease," reprinted from the *Annals of Surgery* for January, 1908. Thirty-six cases were then collected, of which that of C D B — was XII, and it states that "he made a good recovery and gained 30 lbs in weight," also that "he was reported living and well eight years later, with no return of the hemorrhages." Case XIII of the same series is evidently the same patient and accredited to my then chief, Dr Halsted. There had been eight recoveries out of the eleven preceding cases, going back to one by Spencer Wells in 1865. These favorable reports — especially when a success is counted twice — unquestionably are what encourage subsequent operations. This is quite proper, and it is natural that we should continue with these measures, but we must not let ourselves be blinded by incomplete reports of these operative recoveries

Now let us return again to our filing box and see what happened to the patient from Fincastle, Va. Here, in this old rubber band, is a package of cards labeled "Splenic Anemia," with some fifty or sixty references collected in 1900, and you may imagine what the collected literature of the subject must be today. You will find it in the Index Catalogue when you need it

Here is a bundle of notes on the diseases of the spleen and their surgical treatment, and here are several starts at the writing of a paper on the subject, finally abandoned. One of them begins "Nebular as they are, these are essentially borderline conditions of medicine and surgery, and consequently of interest to all," and further, that "some day order may come out of chaos and the disorders now classified as

'pseudoleukemia,' of which Banti's disease appears to be a type, may be found to represent a great diversity of conditions" Some of this might have been written today And here is a postoperative chart by Dr Folhs who was then a fourth-year medical student like some of you here, and he industriously followed this man's blood for two months after the operation, with an almost daily differential count — and you know what this means — though I do not know that we observed anything especially noteworthy except a well-marked poikilocytosis after the operation And here — a letter from Dr Osler urging that these cases be written up from a surgical standpoint And a bundle of reprints on the spleen and its diseases, among them Banti's two papers with a manuscript translation of one of them, made by some one I've forgotten who Then a package of some twenty letters from the patient from about as many addresses For your information as well as entertainment I will quote from some of them, for they are in part amusing and in part tragic This of March 15, 1900

Dear Sir men of good business have advised me to write to the Hospital as it is well known there can be no advertisement put out that will represent the Hospital as well as the scares on my body I can readily see and know and have knowed for some time that I can send many afflicted people there that never will come until they see what has bin don for me I wrote to Dr Henry M Herd on this mail will you see him and pleas have a talk with him and youall can tell me what is the very bes salery they can pay me as I can see some time ago the people I can induce to come it will be a big thing pleas let me hear from you and all about the matter very Respectfully

So far as I know, Dr Hurd did not take advantage of this, for two years later, Aug 12, 1902, we find our patient peddling a patent medicine and attributing his recovery to it

Dear Friend your letter was received last eavening well I am at home now I got sick I am trying to introduce AIM will send you one of my circulars *Please* read it and when you cannot stop blood just call on me for I never fail they like me the company as an agent though I worked to hard Doctor say I Kneed rest and I have liver trouble Kneed some Kind of a mild liver Meadicine all the time AIM is to Strong for me to take very much of it if I was not one of those Push go ahead Kind of fellows I wouldnt be able to do anything at all now you seem to always have so much busines on hand you will never take time to write only a word or too sit up one hour later some night and write a long letter you could do this if you would well when I was operated on I weighed 157 I now weighe near about 140 they say anything that has its spleen removed natural grows thin guess I will dwindle to nothing finaly now write me soon and send me your Picture, &c

A year later finds him married and on a farm — complaining of

Rheumatism I guess I am subject to it all through my body some of it maybe due to me handling the Pruning Shers my mussles seam to be harder than when I come here hard work has made them hard I guess When I get up of

morning I spit up some saliva very bloody looking or almost blood itself I taken some of the Mineral about a yer ago and lots of hard blood Passed from me at Stools for 3 or 4 times just like I used to pass when I had those hemorages etc

Here I must have lost track of him, for there are some returned letters, and there is a gap of six years till 1909, when this from a new address

Dear Doctor one week ago today I was taken with a severe hemorage threw up as much as a pint of blood lost over three quarts of blood all together most of it passed through my bowels this time when I use to have those hemorages eleven years ago before I come to the hospital I would vomate as much as a gallon to a gallon and a half the Dr come to see me the second day the first day he said I must have blood ulcer or cancer of the stomach and that he wanted to go home and read up my case, etc

A wise doctor, particularly as he said the next day

I dont think you have blood ulcer or cancer since I have read up on Dr Oslers work and he did not give me any medicine at all only told me to take a dose or too of oil and I don so I can begin to eat a little something again everybody tells me I work to hard, etc

A good soul, as you will see, but just how much he has benefited by his splenectomy there may be some justifiable doubt³ The matter might be argued both ways, and it might be said that otherwise he would certainly by this time have been in the stage of cirrhosis and ascites Who can tell?

But the last and most important document in this box is a description by W G MacCallum, of the pathologic changes in the spleens of these two patients, which well deserves publication even after these twenty years, if for no other reason than to show how little additional knowledge we have at the present day

Now Gentlemen, I do not mean to imply by what I have told you at this exercise that these are the only books of reference, for there are of course many others equally valuable, in our own and foreign tongues The main thing is for you to get accustomed to certain sources of information, so that you can pick up a subject in its essential details and know how to follow it to its full elaboration

Nor do I mean to imply from what I have told you of the keeping of case records or subject records that this is the only way, for each of you must work out a method more or less applicable to his own characteristics of work The essential thing is to remember that medicine

³ Since this clinic I have again heard from this man (Feb 13, 1920, twenty-one years since his operation) and he reports another hemorrhage in July of 1918 when he vomited about a quart of blood which he attributes to pitching hay, and he still works too hard and would like a position here because he once worked at an asylum in Osawotomie, Kan, and has "the name of being a fine salesman but he doesn't say it boastingly"

is a rapidly changing subject, that no one can keep pace with all branches of it, that if you are going to succeed you will have to be a student of medicine the rest of your days, that this is the time, if any, to establish good habits of work and to learn how to assemble facts relating to disease as they come to your knowledge, so that they may hereafter be useful to you

You must remember, too, that just as the physician may be deluded by blind faith in regard to the efficacy of drugs, so may the surgeon be misled by his operations — the capacity for self-deception is strongly developed in all of us. It is well to keep a reasonably skeptical attitude regarding cures, for then you are never vexed when you find you have been in the wrong. You can learn to practice medicine successfully with a very few drugs well used, and will become the better surgeons for conservatism in the use of the scalpel

To return for a moment to our patient with hemolytic jaundice, whose spleen it is proposed to remove. I see no reason why it should not be done, but at the same time feel some sympathy for his mother's point of view. The risks are not great and, so far as we know, it at least should do no harm, but in the present stage of our ignorance of these disorders, not knowing indeed whether the spleen is the primary seat of the disease, we at least should feel obligated to take every advantage of such an operation to advance our knowledge, by following the case through for a reasonable time before letting it get into medical literature as a presumptive cure. This is a temptation to which the guild of surgeons is particularly prone

THE PATHOLOGICAL CHANGES IN SPLENIC ANEMIA

BY W. G. MAC CALLUM

Of the pathologic examinations carried out in cases of so-called splenic anemia, the most satisfactory are those of Banti, Harris and Herzog, Sippy, Bovaird and Gaucher. Others are very brief indeed and generally limited to the macroscopic inspection of the organs. The cases described by these authors are, however, not homogeneous in their character — those of Bovaird and Gaucher being apparently quite different from those described by Banti, and later by Sippy and Harris and Herzog. With the types described by Bovaird, we have in the other cases nothing exactly comparable. The enormous widening of the venous channels in the pulp with the proliferation of the endothelial cells is not found by Banti in his case. Banti found merely a diffuse new growth of interstitial connective tissue throughout the pulp marking out the venous channels, and a change which he considers primary in the malpighian bodies leading to their sclerosis. These changes, even when taken together with the other details which Banti brings forward, do not seem sufficiently characteristic from the

anatomic point of view to justify the classification of the condition as a separate disease. Such a classification must rest until an etiologic factor is determined largely on the clinical course of the disease. Nevertheless, the objective anatomic description of the cases before us may furnish a clue in time to the etiologic factor.

From *the first case*, we have for anatomic study only the spleen with a macroscopic observation as to the condition of the liver at the time of operation.

Note of Dr. Fleener on the spleen, Nov. 10, 1898.

Spleen measures 18 by 11.5 by 2.5-4.5 cm. and weighs 730 gm. Its anterior edge is rounded—notch partially obliterated. Inferior anterior half of capsule thickened, white and opaque. In the central portion there are lines of calcareous deposit. The capsule is thickened generally but not uniformly, elevated plaques being scattered over the surface. Old adhesions exist over the inferior and posterior border as far back as the hilum which bound the spleen to the diaphragm. Gastrosplenic omentum is adherent to the anterior edge. Cut surface exhibits a remarkable uniformity—its general color is deep salmon or reddish brown only variegated by very prominent trabeculae. The malpighian bodies cannot be made out at all.

A few noncalcareous thrombi, oval in shape, are found in branches of the splenic veins—one was concentrically striated. The consistence of the spleen is very much increased.

Splenic Artery. There is some thickening of the wall which is practically always present in adults, and a moderate degree of tortuosity. Intima generally is smooth. There are, however, thickened opaque plaques situated at the points of branching at the hilum of the spleen.

Splenic vein is apparently normal. What remains of a lymph gland on the hilum of the spleen is easily made out and perhaps enlarged.

Microscopically, one finds the trabeculae definitely increased in thickness throughout the section, the capsule, however, is not markedly thickened. The malpighian bodies are less numerous than in a normal spleen, many of them are quite normal in appearance, while others are abnormal only in their very small size. These immature nodules surrounding small arteries occur in the pulp at quite a distance from the coarse trabeculae. In a few of the larger and more normal looking bodies, there is the pale central area in which the cells lying on the reticulum have a large vesicular nucleus, contrasting with the more deeply staining nucleus of the smaller lymphoid cells. In many instances, as will be observed again in the next case, the central portion of the nodule is occupied by a dense mass of the small lymphoid cells, the peripheral cells being slightly larger and less closely arranged. No progressive sclerotic process such as Banti described is seen in these malpighian bodies, nor has it been possible to find any fibrous nodules which might have resulted from such sclerosis. The fine reticulum normally supporting the lymphoid cells is perhaps a little coarser than normal. None of the hyaline masses enclosing cells and

fragments of nuclei, such as Banti described, are found here, although it may be mentioned in passing that it is by no means unusual to find such masses in the greatest variety of conditions, and they can therefore hardly be considered in any way characteristic of this disease.

In the red splenic pulp the changes are definite enough to attract immediate attention, but before detailing them it may be well to review briefly the main points in the histology of this tissue as brought out in the recent papers of Weidenreich, Mall, Thoma and others. The question as to whether or not there is an open or closed blood circulation we may leave aside, as it scarcely concerns us here. More important for the comprehension of these changes is the excellent description of Weidenreich of the minute structure of the venules and arterioles, and the intervening tissue which goes to make up the red pulp. The walls of the arterioles present no especial peculiarities if we except the curious sheath which covers the vessels just before their termination in the capillaries. The wider venules into which these capillaries empty, however, have a very remarkable structure. They are of almost uniform width and lie closely plaited together so as to constitute the greater bulk of the tissue. Their walls consist of a basketwork or network of circular and communicating fibrils very much like the markings on a tracheid vessel in the wood of a plant stem, inside of which there is an extremely delicate basement membrane on which the elongated lining endothelial cells are longitudinally arranged. There has been some discussion as to the nature of the circular fibrils. They stain weakly with Weigert's elastic stain, also with the phosphomolybdic hematoxylin of Mallory, and resist for a time pancreatic digestion so that they may be isolated by digesting a section on a slide.

The endothelial cells have a long, narrow cell body, the nucleus, which has one or two indentations, lies in an expansion of the protoplasm in the middle, and is somewhat elevated above the basement membrane so that in cross section of the venule it projects into the lumen. Between these venules there is a supporting reticulum, the fibrils of which anastomose with those forming the network about the venules. Definite connective cells and fibers are present also in small numbers, and there are in the meshes of the network abundant free cells including red blood corpuscles, polymorphonuclear leukocytes and other wandering cells of the type of the lymphoid and plasma cells. In certain conditions, such as acute infection with the pyogenic cocci, we may have an acute splenic tumor, the chief characteristic of which is the great increase in these free cells which form the true pulp cells of the spleen, in contrast with that type of acute splenic tumor which occurs with typhoid fever and in which the hyperemia and endothelial proliferation dominate the picture.

In the case before us, we have, as was mentioned before this digression, changes which are obvious at the first glance. The splenic pulp is markedly poor in cells and the venous channels, ordinarily very thin walled, and to be outlined only with some difficulty on account of their being masked by the great number of cells, are here stouter and extraordinarily distinct. All of the features described above are extremely evident. The intervening tissue, however, has been converted into a fibrillated mass containing only a very few cells of the types usually seen there. Rounded mononuclear cells closely resembling plasma cells are most abundant, polymorphonuclear leukocytes are sometimes seen, and mononuclear and polymorphonuclear eosinophils are quite numerous. There is, as one can determine by suitable stains, a great increase in the connective tissue between the venules. Wavy strands of white fibrous tissue course along here although, as mentioned by various writers, there is no evidence of cell proliferation to give rise to all that new tissue. They lean to the view that the cells of connective tissue nature already present produce more interstitial substance and thus cause the sclerosis of the tissue.

The venules are not distended and do not reach the size ordinarily seen in cases of advanced chronic passive congestion, the condition which perhaps most of all resembles that seen here. They are not even filled with blood in the section, although of course that fact may be due to the draining of the spleen of its blood at the time of the operation. Many mononuclear cells are seen in these venules as well as in the large veins. They may be in large part desquamated endothelial cells, since they are by no means so abundant in the peripheral portions of the section, or in sections in which the fixation of the tissue has been very accurately carried out.

A neighboring lymph gland shows no especial pathologic alterations. There is no deposit of pigment of any sort — no phagocytic cells are to be seen, nor are there any other evidences in the spleen of an active hemolysis. One or two milary tubercles with beginning necrosis of the center and giant cells are found in the pulp.

In *the second case* the spleen was removed successfully and the death of the patient occurred ten days later from an extensive hemorrhage from a dilated esophageal vein.

The macroscopic examination of the spleen was recorded in the following note:

Spleen removed by Dr. Cushing. Spleen is much enlarged. Dr. Cushing said that it is much smaller now that blood is expressed than before the operation. It weighs 1,000 gm and measures 25.5 by 14.5 by 8.5 cm. It is somewhat irregularly lobulated.

The capsule is not much thickened in general, but presents lines of opacity forming a network.

Over the convex surface is an area 11 by 4 cm where the capsule is much thickened and contains calcified plates. There are a few small nodules of such thickening scattered here and there over surface. The vessels at the hilum are not thrombosed. The arteries are markedly sclerosed. The veins appear normal and rather wide. The main splenic vein measures 2 cm in circumference, i. e., about 7 mm in diameter.

The spleen in general is soft and flabby and is not dense and firm as in the case of a spleen of chronic passive congestion. It has rather a pale color. On section the spleen has a similar pale red color. The malpighian bodies are seen with great difficulty. They are apparently diminished in size. The blood vessels are very prominent. The walls are thickened and opaque, gaping open on cut section. The trabeculae are also much increased in relation to the pulp. The pulp is somewhat translucent, and trabeculae can be seen as opaque lines running beneath the cut surface. The spleen though soft is extremely tough, reminding one of very soft rubber. A small portion can be crushed only with difficulty by the fingers. The pulp is thus not friable, and this character together with a slight translucency gives one the impression that there is an increase in the connective tissue throughout. It has nothing of the opaque velvety appearance of acute splenic tumor, and the cut surface is quite smooth and glistening.

Autopsy MacCallum Jan 9, 1900 Autopsy No 1469

Anatomic Diagnosis *Primitive splenomegaly Operation for removal of spleen Cirrhosis of liver Interstitial pancreatitis Hemorrhage from esophageal varix*

The body is that of a well nourished man, 165 cm in length. There is a wound in the left hypochondrium 20 cm in length which extends to the crest of the ileum. It is completely closed by sutures. The peritoneal cavity contains about 100 cc of blood-stained fluid.

The thoracic viscera are practically normal except for a slight arteriosclerotic thickening of the aortic valves.

The liver weighs 1,300 gm, and measures 24.5 by 14.5 by 9.5 cm. It is distinctly smaller than normal. The surface is roughened, but not definitely hobnailed. It is yellowish brown in color with a slight greenish tint, and both from the outside and on the cut surface has a translucent appearance. The consistence is firmer and more elastic than normal. The lobules are not very sharply outlined, but interlobular strands of grayish tissue can be made out here and there. The portal vein at its entrance into the liver is occluded by a thrombus.

The peritoneum about the site of the operation is not injected. There is no hemorrhage and no peritonitis, except that the omentum and stomach are delicately adherent to the diaphragm. The diaphragm is somewhat congested, and severed veins are everywhere plugged with dark thrombi. The splenic artery is tortuous in its course over the tail of the pancreas where it is ligated. The splenic vein is wide and accompanies the artery, it is also ligated. Both are occluded by thrombi of which that in the artery is firm and lamellated. The wall of the vein is perhaps slightly thickened. The thrombus in the lumen, which has a central softened portion, extends along the vein into the portal, where it rolls up and occludes the vein at the hilum of the liver. The inferior mesenteric, diaphragmatic and gastric veins and left renal veins are occluded by thrombi. That in the portal vein is, however, limited to the hilum of the liver.

The stomach and duodenum are distended with bloody fluid and clots, the stomach containing over a liter. The gastric mucosa is pale and normal looking. One or two thrombosed submucous veins are seen through the mucosa. In the esophagus at its lower end there are widely dilated submucous veins, most of which seem to be thrombosed. One just beneath the mucosa is apparently the source of the hemorrhage, for there is a small punched out ulcer opening directly into it, as shown in the illustration.

The pancreas was slightly injured at the tip of the tail and there are scattered areas of fat necrosis in the neighborhood.

The kidneys are large, but show no especial pathologic alterations. In the fat about the splenic flexure of the colon there is an accessory spleen about 2 cm. in diameter resembling, on section, the main spleen. The inguinal and femoral glands are enlarged, white and firm.

Bone marrow of the femur is pale purplish red in color and quite firm. The fat is quite masked by the cellular elements.

All the organs are very anemic and the heart's blood thin and watery.

Microscopically, the changes are most marked in the spleen and liver. The bone marrow proves to be exceedingly rich in cells of the types usually found in actively proliferating marrow. Erythroblasts are very numerous indeed. The lymph glands show no characteristic abnormality. Special attention at that time was not directed to the hemolymph glands, and none of them can be found in the preserved material.

The accessory spleen is completely necrotic, its vessels being thrombosed and entirely occluded. What remains of the architecture, however, is enough to show that it had undergone the same changes as the main spleen. The kidneys microscopically are practically normal, except for a very insignificant increase of connective tissue in certain areas. In the pancreas there is a well marked chronic interlobular and intralobular pancreatitis without very extensive degenerative changes in the parenchyma cells. The changes in the liver are very slight as compared with those in the spleen. There is a cirrhosis, that is, there is an increase in the connective tissue in the portal spaces, but this is not an extensive new formation of tissue, such as one sees in alcoholic cirrhosis. The bands of fibrous tissue are narrow and have not the appearance of having been recently formed—they are instead very dense and poor in cells—newly formed bile ducts are almost entirely wanting in them. The liver cells show a good deal of fatty degeneration, and there is great inequality in the size of their nuclei.

The veins in the submucosa of the stomach, especially about the cardiac orifice, are distended with blood.

The sections of the spleen show no definite thickening of the capsule, the trabeculae, however, are much thickened. The alterations of the pulp and malpighian bodies resemble in general those seen in the first case. The malpighian bodies are not numerous. Indeed, as compared with the normal spleen, very few of them are to be found in a

section, but this may, of course, be due to the enormous increase in the bulk of the red splenic pulp which separates them widely. They are in general normal in appearance with the exception of a diffuse thickening of the reticulum. Often there is the frequently described central area with large pale nuclei in many of which mitotic figures are visible — fragments of nuclei and occasionally fine fragments of hyaline material are seen between these cells. None have undergone any extensive sclerosis and it has not been possible to find one completely converted into a fibrous mass.

The red splenic pulp is greatly increased in amount — there must be a great new formation of vessels, because the increase in the interstitial tissue alone does not seem to be sufficient to account for the enormous enlargement of the spleen. The pulp too consists, as in the preceding case, almost exclusively of closely matted venules whose walls are rather more definite than normal, but which are not dilated to a diameter greater than normal. In the interstices there is a distinct increase in the connective tissue which runs in wavy lines between the venules. Mallory's connective tissue stain brings out a fairly dense network in which the venules lie. In digested and stained preparations, however, the reticulum which becomes isolated as a delicate basketwork does not appear to be very greatly thickened over the normal, and indeed the individual venules are not especially stouter than the normal. Nor in all parts is the distribution of the new connective tissue homogeneous — there are areas in which the venules lie immediately together, while just adjacent to them there are bundles of connective tissue fibers separating the blood channels. Apparently, therefore, the change in the bulk and consistence of the red splenic pulp is due to a great increase in the venules and their closer packing together on account of the lack of abundant pulp cells together with a definite formation of new connective tissue throughout.

As in the preceding case the cells in the interstices are very few in number. Those which are left are of the lymphoid and plasma cell type with some polymorphonuclear leukocytes and relatively abundant mononuclear and polymorphonuclear eosinophils, some of which are so large as to form very striking objects. Large giant cells also sometimes occur in these spaces, they are irregular in outline and contain several nuclei clumped together in the middle.

Here, as in the lymph glands, the tests for iron holding pigment were negative.

Finally, we have the spleen from the case reported by Dr. Osler⁴ as Case XVI. This spleen was also enormously enlarged, measuring 24 by 14 by 7 cm. The surface is somewhat roughened by shreds of

4 Osler, William. Anemia Splenica (second paper), *Tr. A. Am. Phys.*, 1902

old adhesions, but the capsule was not particularly thickened. On section, it has the same semitranslucent grayish lilac or grayish red color as in the preceding case, the cut surface is quite smooth and sinks slightly into a concavity. The malpighian bodies are not at all prominent, but the trabeculae and vessels are quite conspicuous. The spleen has the elastic rubbery consistence described for the others. The blood vessels at the hilum are somewhat dilated, but show no other abnormalities.

Microscopically, the trabeculae are very inconspicuous and indefinitely outlined, they seem to merge into the surrounding tissue. There are a few small hemorrhages in the splenic substance beneath the capsule as well as elsewhere scattered in the pulp, probably these were due to the handling of the spleen during the operation.

The splenic pulp is pale and anemic, and there are strands of pale staining connective tissue running throughout it and separating quite widely the venules. The new growth of connective tissue is far more marked here than in the other cases, and with Mallory's stain gives a blue meshwork of coarse fibers with very narrow meshes. The venules, indeed, seem narrower than normal. The basketwork of the reticulum fibrils in the spleen about the venules seems to be denser than normal, it is very intimately associated with the connective tissue of new growth.

The connective tissue between the channels is exceedingly poor in cells, it stains pale pink and has a finely fibrillated appearance, with Mallory's stain it takes a deep blue and the fibrillation is more evident. Definite connective tissue cells are relatively few in number, and no evidence of mitosis has been made out. Free cells of the lymphoid and plasma cell type occur, however, sparingly distributed, and there are quite numerous mononuclear and polymorphonuclear eosinophils. The last are so abundant as to be quite a striking feature in the section, occurring also in the blood channels.

The malpighian bodies are few in number in a section, but are practically normal. The central cells are generally the smaller and more closely crowded together, while the peripheral are larger and more loosely arranged, large epithelioid cells occur scattered among them. There is no evidence of any primary sclerosis of this part of the tissue. They rarely show any centers of active cell proliferation, and areas of cell degeneration and hyaline necrosis are quite as rare.

In these three cases therefore, we have practically identical conditions in the spleen. In all, the malpighian bodies show practically no pathologic changes of any significance. They are scattered by the changes in the pulp and often small, but no more characteristic changes occur. In the pulp, there is apparently a great increase in the number of the venules which are not dilated, but from the loss of cellular tissue

between them have come to compose the greater part of the tissue. The basketwork of fibrils surrounding these venules seems not to be much altered, but there is a definite new growth of connective tissue between the venules. The endophlebitis described by Banti has not been made out in these cases. There is no evidence of great hemolysis in the spleen or elsewhere in the body, if we except the regenerative activity of the bone marrow. In one of these cases the man is apparently well two years after the splenectomy, in one there is slight cirrhosis of the liver, while in the third we have no evidence as to the condition of the liver. Speculation as to the nature of the process will probably lead to no definite result. Certainly the condition is not such as is characteristic of the ordinary chronic passive congestion, there are no extravasations of blood with hematoidin formation, no such widening of the venules and withal a far greater new growth of connective tissue than is ordinarily found in the spleen of chronic passive congestion. There can be no question of malarial infection as an etiologic factor, for there is nothing in the history to indicate this, and there is none of the characteristic malarial pigmentation. It does not seem unreasonable to suppose that some toxin perhaps with a mild hemolytic action may act primarily to produce an enlargement and induration of the spleen and later a cirrhosis of the liver.

DIAPHRAGMATIC HERNIA

ARTHUR DEAN BEVAN, M D

CHICAGO

Since the general introduction of roentgen-ray examination of the stomach and intestine after the introduction of barium solution, a great deal of study has been devoted to the subject of diaphragmatic hernia. Many of the cases that before the introduction of the roentgen ray and barium studies could not be diagnosed can now be clearly seen, and definite and accurate diagnoses can be made. This newer method of examination has shown that diaphragmatic hernias are much more common than was formerly believed to be the case. In the days before roentgen-ray examination I was seldom able in my own work to make a definite diagnosis of diaphragmatic hernia. I have recently been able to study with my medical colleagues four of these patients on whom we have subsequently operated. It is my intention to report this clinical experience.

CLASSIFICATION OF DIAPHRAGMATIC HERNIA

Before taking up the details of these cases, however, I should like to discuss briefly the subject of diaphragmatic hernia in general. The cases which we find reported in the literature under this general term can, as a matter of fact, be classified under three heads: first, congenital hernias of the diaphragm, second, acquired hernia in the same sense that the ordinary inguinal hernia of the adult is called an acquired lesion, third, traumatism of the diaphragm, either from stab wounds, gunshot wounds or subcutaneous ruptures in which the opening in the diaphragm permits of the passage of the intestinal contents into the thoracic cavity. When these cases go on to recovery without any operation and leave a resultant traumatic hernia, they may fairly be classified under the general term of diaphragmatic hernia. On the whole, however, injuries of the diaphragm leading to the escape of the abdominal contents into the thoracic cavity are better classified as gross traumatism of the diaphragm without including them under the general title of diaphragmatic hernia.

Congenital hernias of the diaphragm occur at several points, one presents itself as a weak point in the diaphragm at the junction of the ensiform process and the costal cartilages. Here a triangular area not covered by muscle is found fairly constantly, and sometimes it is weak enough to permit the development of a hernia, with some of the abdominal contents escaping into the thoracic cavity. A second weak point is found between the

psoas muscle and the ribs, posteriorly. Other congenitally weak points in the diaphragm are the esophageal opening and the openings for the venae azygos and the phrenic nerves. At any of these points and at other portions of the diaphragm, congenital defects may exist which permit of a diaphragmatic hernia. There are cases reported in which there is an entire absence of the diaphragm congenitally.

Not infrequently these cases of congenital diaphragmatic hernia produce few if any symptoms, and a number of cases have been found postmortem in which the history of the individual case gave no evidence that the condition produced any distress or interfered with ordinary functions. Again, it is quite possible for the individual to continue for years in comparatively good health with a congenital diaphragmatic hernia, and then suddenly a strangulation occurs, producing a picture of intestinal obstruction, which, of course, would be very difficult to diagnose and which would then be found either at operation or postmortem.

In the congenital type without any symptoms, in which the condition is discovered accidentally in making a gastro-intestinal examination of the patient with the roentgen ray and barium, the question of the indications for surgical interference would be relative and not positive, and one would want to study such cases with a great deal of care and determine absolutely that the condition was giving rise to symptoms or presented a sufficient menace before undertaking any operation for its correction.

The literature of injuries of the diaphragm from stab and gunshot wounds comes in large part from the Latin countries, where the knife is a more favorite weapon than it is here in America or in Great Britain or Germany, although we in this country have had a fair number of these cases reported from gunshot wounds, stab wounds and contusions. During the World War, a large number of these cases occurred from high explosives and gunshot wounds. A considerable number of these cases were associated, in addition to injury of the diaphragm, with more or less extensive lesions of the contents of the abdominal and thoracic cavities, and often, of course, with other injuries which overshadowed the diaphragmatic injury. In cases of stab wounds of the chest with injury of the diaphragm and resultant hernia, experience has shown the wisdom of adopting the trans-thoracic route for exploration and repair. In cases in which the injury is primarily of the abdomen with great probability of serious injury to the abdominal viscera, abdominal exploration should be made to determine the condition of the abdominal contents, the question of perforation of the stomach or intestine, hemorrhage, etc. If it is not found, or in the event that it is found and repaired, an attempt should then be made to repair the injury of the diaphragm.

through the transabdominal route. If this is not successful, a transthoracic incision should be made, and the incision closed in that way. The experience of operating on these diaphragmatic injuries by the transthoracic route, opening the pleural cavity and repairing the diaphragm, has shown that it is usually possible, that the production of a temporary pneumothorax is not, as a rule, a serious matter, and that the operation can be performed without intratracheal anesthesia or the pressure cabinet. When infection does not occur, the immediate closure of the wound is followed by a rapid absorption of the air in the chest, and without other complications, the recovery of the patient.

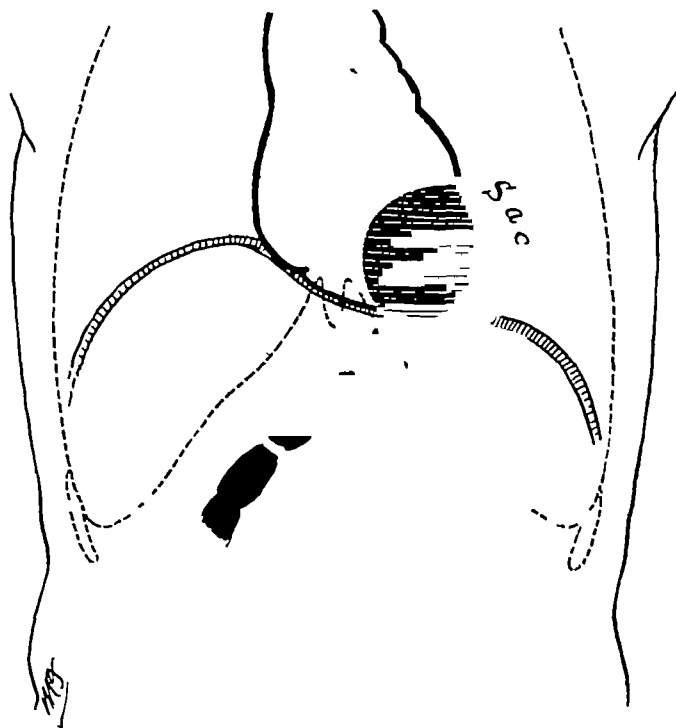


Fig 1—Outline of roentgenograms showing hernial sac above esophagus

ACQUIRED HERNIA OF THE DIAPHRAGM

The particular type of hernia which I desire to discuss is what I believe should properly be classed as an acquired hernia of the diaphragm. I would compare this to the acquired inguinal hernia that we ordinarily see. My experience has been limited to four recent cases of this type, but it leads me to believe that these acquired hernias of the diaphragm occur always at the esophageal opening just as inguinal hernias occur at the external abdominal ring. The parallel between these esophageal diaphragmatic hernias and inguinal hernias passing along the spermatic cord or the round ligament is

very close. We have in both instances a weak point, this particular portion of the wall being weakened by the passage through it of some structure, in one instance the cord and in the other instance the esophagus. At this weak point, probably from gradually increased intra-abdominal pressure, the peritoneal sac first makes its way and then some of the abdominal contents are forced into this sac. In the case of diaphragmatic hernia, we almost never have a hernia on the right side of the diaphragm on account of the position of the liver, and the contents that pass through at the esophageal opening are, therefore, the contents of the left side of the abdominal cavity in this order: first and most commonly, the stomach, then the great omentum, then the transverse colon, and lastly, in some rare cases, the small intestine. Like inguinal hernias, these hernias are in part reducible and in part irreducible because of the formation of adhesions.

The clinical picture of diaphragmatic hernia of the stomach is by no means a constant one. The picture that I have seen has been, first, stomach distress, sometimes daily and sometimes coming on at longer intervals, the daily stomach distress is sometimes associated with pain coming on some time after the ingestion of food, simulating somewhat the picture of ulcer, sometimes that of gallstone disease and sometimes associated with vomiting, simulating the picture of pyloric obstruction. Occasionally, these patients have pain only at long intervals and then apparently when they have overeaten or eaten something that has disagreed with them, perhaps forming a good deal of gas. In one of our cases the pain was particularly excruciating and came on at such irregular intervals as to suggest strongly the possibility of gallstone colic attacks.

The clinical picture of the cases in which the colon is involved may be suggestive of a beginning obstruction from carcinoma, a partial intestinal obstruction relieved by cathartics and enemas, with a disappearance of the symptoms and then a recurrence after an interval of days or weeks. Of course, the picture of strangulation of the small intestine or of the colon gives the picture of intestinal obstruction from an unknown cause unless definite evidence of a diaphragmatic hernia can be obtained with the roentgen ray. Of course, in all these cases, a very careful history should be taken and a very careful analysis made of the evidence obtained. After all, a definite diagnosis must rest on fluoroscopic examination and the taking of roentgenograms. The evidence is very gratifying. Fluoroscopic examination in one of these cases with a barium meal introduced into the stomach showed a filling of the stomach and then a gradual filling of the pouch above the diaphragm, which could be easily seen and outlined (Fig 1). When the colon

is involved, the best evidence is obtained by the introduction of a barium solution into the colon followed by fluoroscopic examination and the taking of roentgenograms. In the few cases in which the small intestine is involved, the evidence of involvement of the small intestine is confusing. Sometimes, however, this fact can be definitely

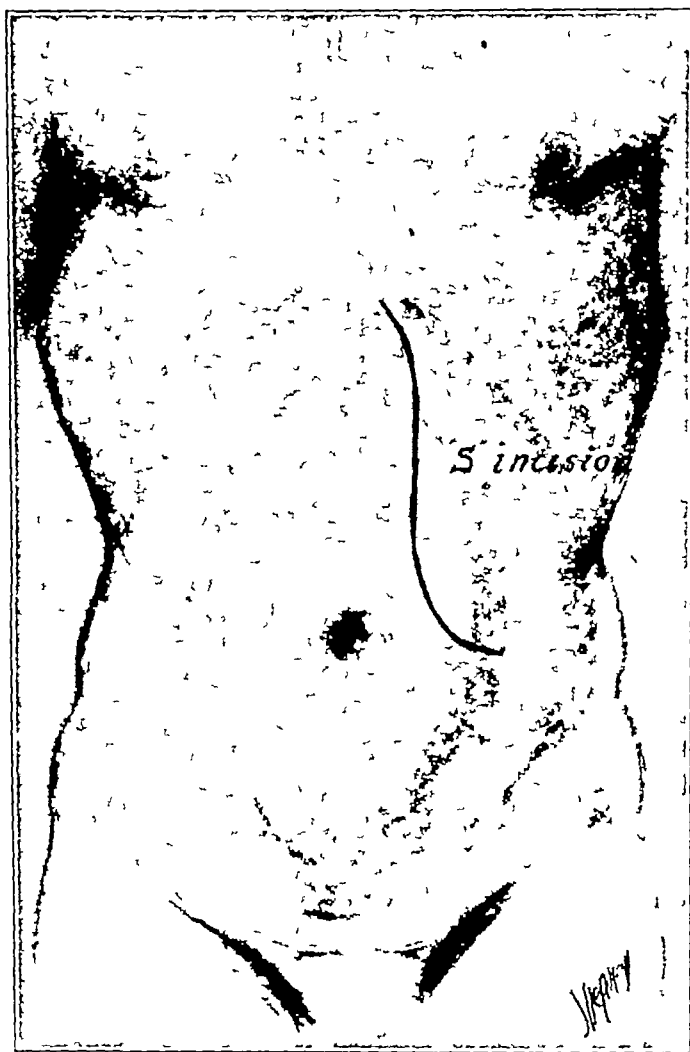


Fig 2—S-shaped incision on left side

determined from the roentgenograms, especially roentgenograms or fluoroscopic examination made over different periods of time after the introduction of the barium solution.

SURGICAL THERAPY

In cases in which a definite diagnosis of diaphragmatic hernia can be made and the patient presents symptoms which can be ascribed to this lesion, unless there is some very strong contraindication, an

attempt should be made to cure the patient by operation. We have worked out a technic which has seemed quite satisfactory. The first essential is a wide exposure which will enable one to reach the esophageal opening and to reduce the hernia and close the opening so as to prevent recurrence of the condition. After a careful study, I have come to the conclusion that the large S-shaped incision made on the left side, such as we have for a number of years employed in our splenectomies (Fig 2), answers the purpose better than any other. The incision should be carried well down, either to, or an inch or an inch and a half below, the umbilicus, and carried through

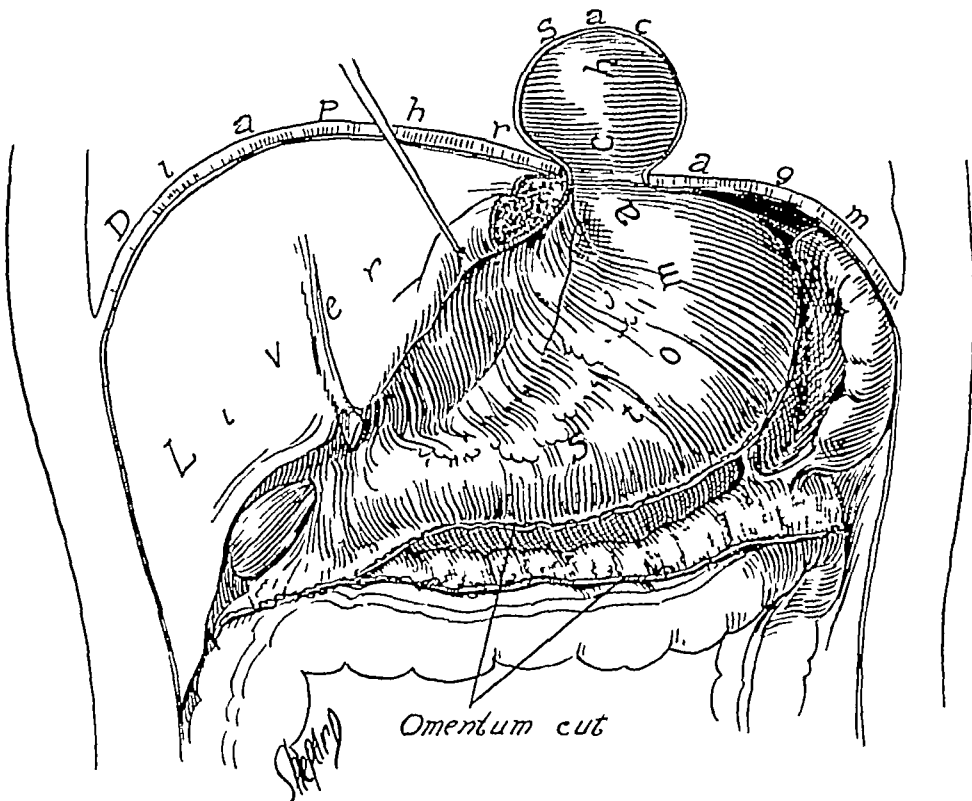


Fig 3—Stomach in diaphragmatic hernia

the rectus muscle at the lower limb of the incision. Large abdominal pads are then used to hold back the abdominal contents. One wants complete relaxation under a general anesthetic. I have operated with these patients in the recumbent position. I have never tried using the reversed Trendelenburg with the idea of allowing the abdominal contents to pass to the lower part of the abdomen, and yet I believe this might be very properly considered. Holding the abdominal incision widely apart with large retractors, the hand is passed into the abdominal cavity in front of the stomach to the

esophageal opening and the contents of the diaphragmatic hernia gently pulled down into the abdominal cavity, whether it be the stomach, intestine or omentum. When the hernia is reducible this is very easily done, and one sees at once the exact condition at the esophageal opening through which the abdominal contents have passed into the thoracic cavity (Figs 3, 4 and 5). The closure of the opening is comparatively simple, either with good sized catgut or with silk or linen, I believe preferably catgut. With a large full curved noncutting needle the pillars of the diaphragm are firmly grasped and the hernial opening is closed (Fig 6).

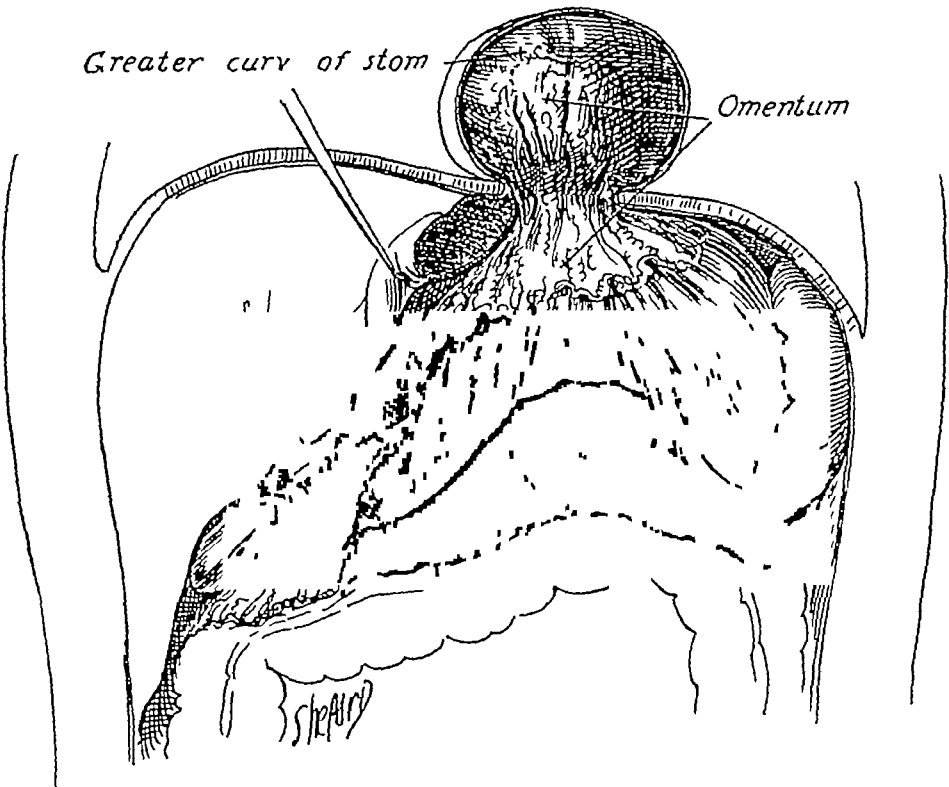


Fig 4—Hernia of omentum and greater curvature of stomach

I believe it is well for the surgeon to study the anatomy of the diaphragm carefully before performing this operation, as this will give him courage to take a large bite of the muscular pillar in each suture. One can employ either a continuous suture or interrupted sutures. Possibly, on the whole, interrupted sutures are to be preferred. With three, four, or in some cases, five or more sutures, the opening is closed down snugly around the esophagus. This of itself will prevent an immediate recurrence of the hernia and the

passage of the contents into the thorax. In order, however, to add additional security, we have in most of our cases sewed the stomach to the diaphragm or to the parietal peritoneum (Figs 7 and 8). In some cases, it is comparatively easy to sew it to the diaphragm for several inches. In our last case, we found this was difficult, and we found that it was necessary to sew the anterior part of the stomach, which had a great tendency to pass back into the thorax, to the parietal peritoneum.

The after-treatment is simple. Physiologic sodium chlorid solution is given by rectum for twenty-four or forty-eight hours, and then

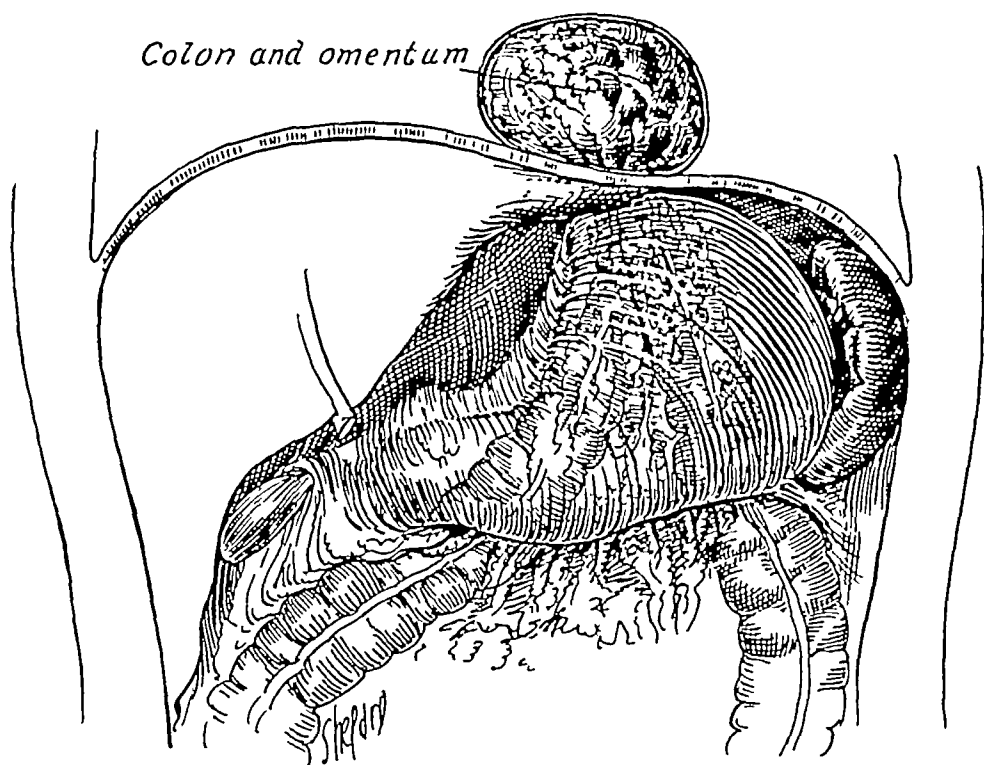


Fig 5—Colon and omentum in diaphragmatic hernia

the patient is fed very much after the ordinary gastro-enterostomy or pyloric resection—small amounts of food every hour. On account of the large size of the incision, we have lately been using three or four button sutures in addition to the ordinary closure.

The results have been admirable, three of the patients making complete recoveries. One patient died, this outcome, however, was due not to the technic, but to the pathologic condition. This was a very interesting case in which the diagnosis of diaphragmatic hernia, part of the stomach passing into the thoracic cavity, was definitely established by roentgenograms. The woman was quite distended, and we believed that the distention was due to the hernia. At operation,

we readily reduced the stomach, closed the opening and performed what we thought was a very satisfactory operation, expecting the patient to proceed to a good operative recovery. Unfortunately, however, she became very greatly distended, and in spite of medication and washing out the stomach, this continued, and she died shortly after the operation. We were able to obtain a postmortem examination, which revealed a small circular carcinoma at the splenic flexure, which was probably an important etiologic factor in the production of the diaphragmatic hernia and the condition which had gradually produced distention of the abdominal contents and increased intra-abdominal tension with resultant diaphragmatic hernia. I present a brief summary of these four cases.

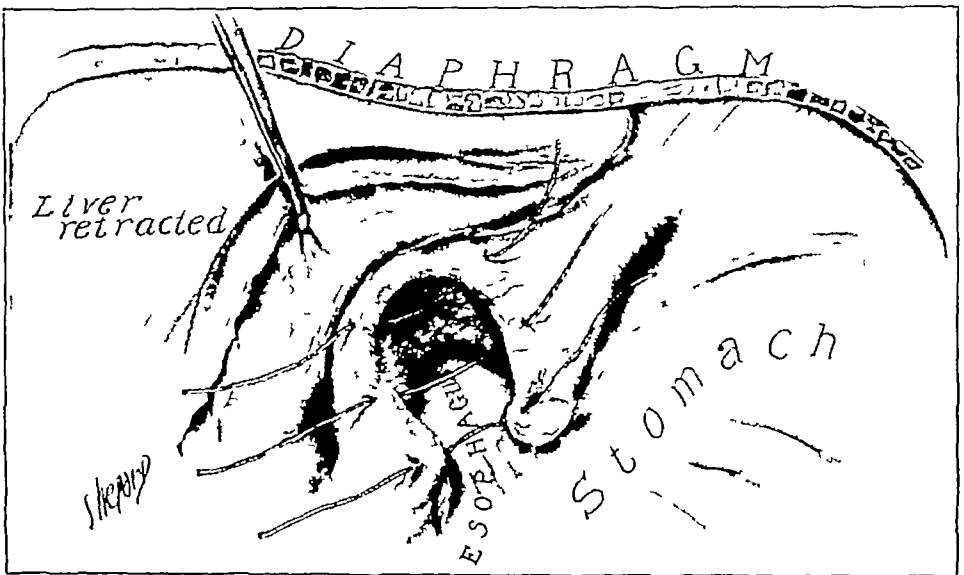


Fig 6—Sutures placed for closure of hernial opening

REPORT OF CASES

CASE 1—History—Mrs A W, aged 57, on the service of Dr Sippy, who complained of pain in the epigastrium, a dull ache over the gallbladder region, cramplike pains in the abdomen, loss of weight and constipation, dated the onset back three years, at which time she had had a very severe attack of "heartburn" coming about one and one-half hours after breakfast. She belched up sour material but did not vomit. The attack lasted until noon. From six to eight months later, the patient began having severe attacks of pain in the epigastrium coming on at the time of eating, or immediately afterward. They were of short duration (from ten to twenty minutes), but gradually increased in severity and frequency so that lately they had caused her to double up. At times during an attack, there was a cramping sensation. The attack seemed worse when she was eating soups or soft things which could be taken quickly. She had never been tender to touch or pressure even during an attack, but had noticed that the jolting of walking increased the pain.

Belching gave the quickest relief, and she was often able to finish her meal after an attack. Besides the attacks which came on during meals, she had had frequent short attacks of sharp, cramplike pain beginning in the right hypochondrium and extending to the umbilicus. These attacks came on when the patient stooped over, and were severe enough at times to require an opiate, but they lasted only a short time. The patient had lost about 25 pounds in weight during the past six months. The maximum weight was 208 pounds, now it was 173 pounds.

Examination—The roentgen ray revealed the fact that fluid food passed into the esophagus, apparently part way into the stomach and thence into a pouch above the diaphragm. After this pouch had been filled the rest of the small stomach pouch below this was filled up by the bismuth meal. Possibility of a diverticulum from the lower esophagus had been considered.

Diaphragmatic hernia was diagnosed.

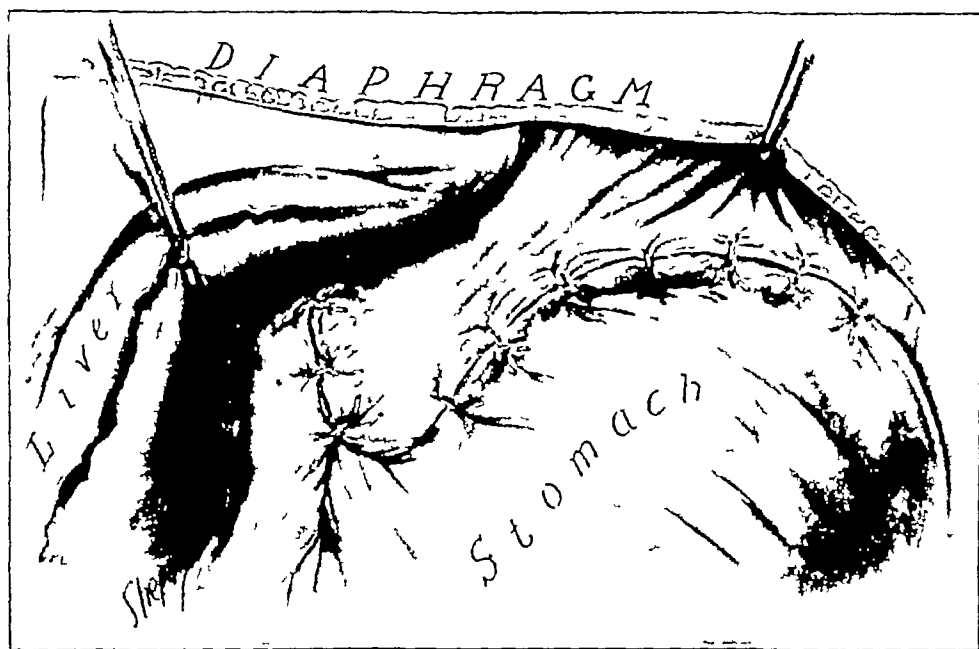


Fig 7—Hernial opening closed, stomach sutured to diaphragm

Operation and Result—Under ether anesthesia, a large S-shaped incision was made through the left rectus. A large part of the stomach and some omentum were found in a hernia of the diaphragm at the esophageal opening. These viscera were pulled down into the peritoneal cavity and the opening in the diaphragm closed by four Pagenstecher linen sutures, the part of the stomach reduced from the esophageal opening was sutured to the diaphragm and the anterior part of the stomach was sutured to the parietal peritoneum, the wound was closed and sealed. The wound healed in good condition and the patient left the hospital fifteen days later. A roentgen-ray examination after operation revealed the stomach normal and entirely below the diaphragm.

CASE 2—History—Mrs E. L., aged 55, with a blood pressure of 132 systolic and 94 diastolic, was admitted to the Washington Boulevard Hospital, service of Dr Sippy, complaining of pain in the abdomen, vomiting, difficulty in

swallowing, weakness, loss of weight and constipation. The present illness had begun suddenly ten weeks before with sharp pain in the abdomen just above the umbilicus associated with vomiting, jaundice and a general feeling of depression. At onset, the pain was not severe except when the patient was

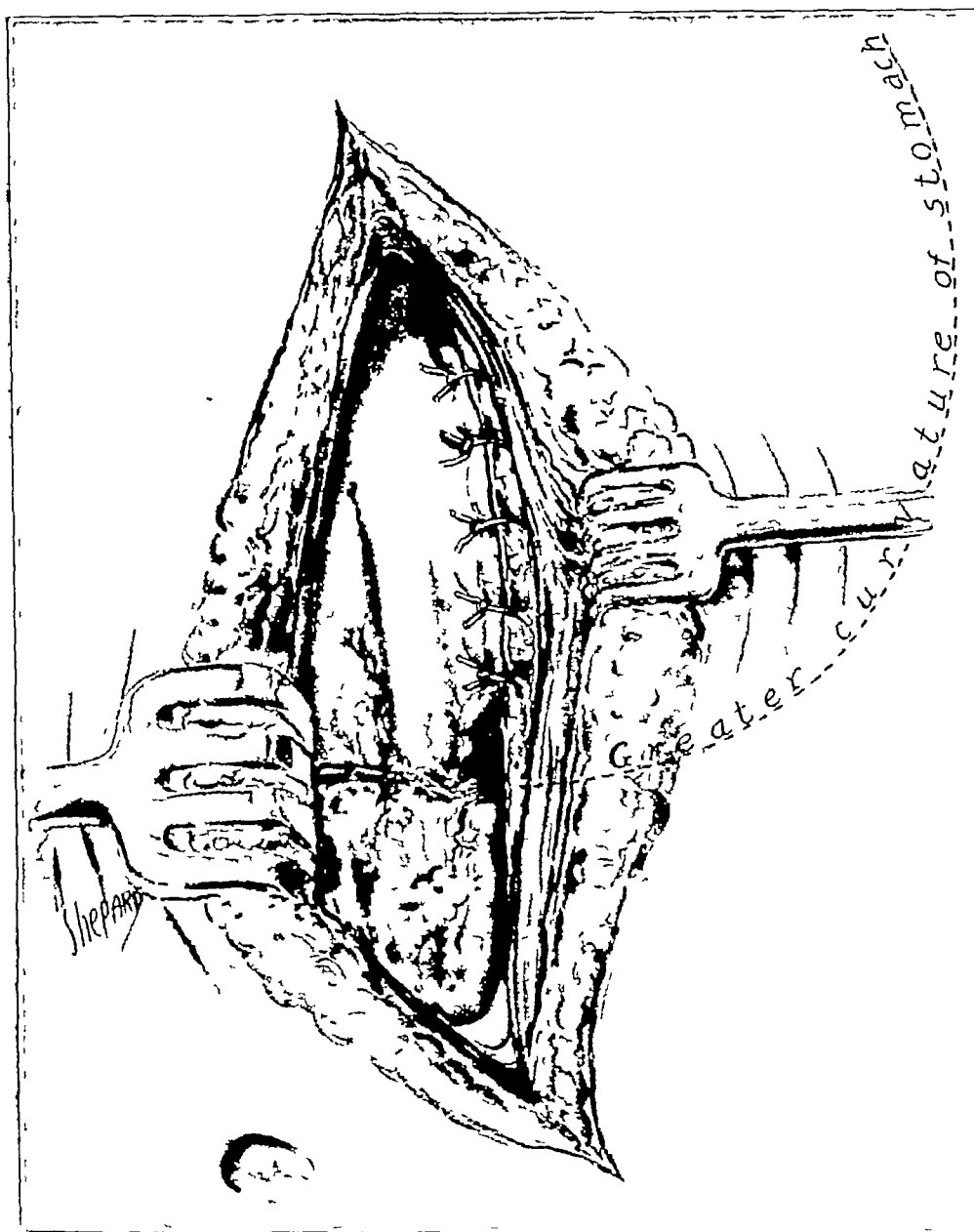


Fig 8—Stomach sutured to abdominal wall

up and about or after the ingestion of food. Six weeks before, the condition had grown gradually worse, and the patient had been forced to remain in bed. The pain and vomiting had markedly increased and had been very severe, at times independent of the ingestion of food. The pain was sharp, cramplike

in character, extended usually across the abdomen just above the umbilicus, and always preceded attacks of vomiting. The right side had been relatively free from pain. Difficulty in swallowing solid foods had begun six weeks before. The food seemed to stick just above the stomach and caused the patient to vomit immediately. There was no difficulty in drinking small amounts of liquid at a time. The patient had always been constipated and had been taking cathartics about twice a week for several years. For the last six weeks, she had been unable to obtain a bowel movement without an enema, and a very slight movement with one. She also had noticed rumbling and gurgling associated with cramps in the abdomen several times a day. She had lost 57 pounds in weight during the last three months.

Physical Examination—Pyorrhea alveolaris was present. The chest was negative. The abdomen was pendulous and flabby. No local areas of ten-

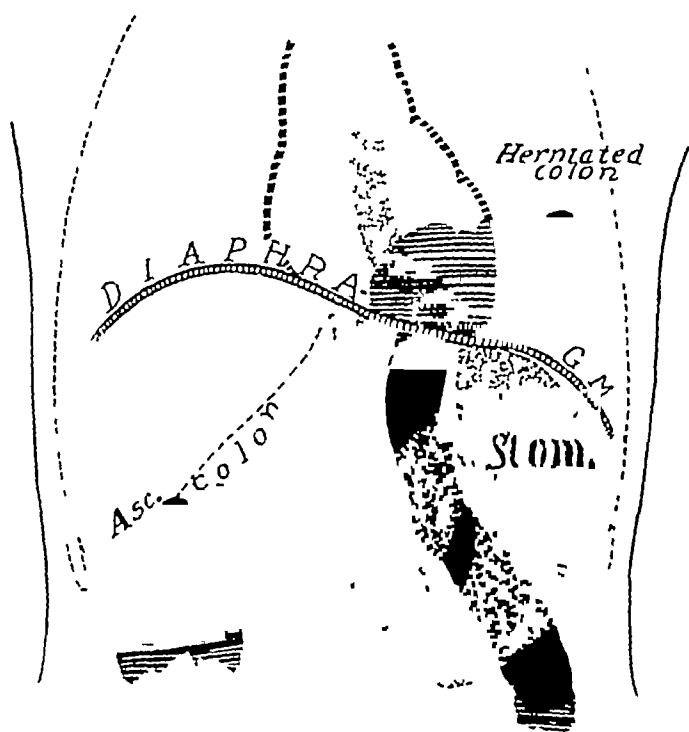


Fig 9—Transverse colon in diaphragmatic hernia

derness and no tumor masses were palpated. Three attempts to pass a stomach tube were unsuccessful. Obstruction was encountered each time at a distance of $15\frac{1}{2}$ inches from the incisor teeth. Attempts to swallow a string were unsuccessful on account of vomiting.

Fluoroscopic Examination—As barium was swallowed, it was seen accumulating in the apparent position of the lower end of the esophagus. The stomach was shaped like an inverted V, with little or no respiratory mobility on the right side and accurate mobility on left. There was a deep notch in the fundus, and the lower border of this notch was continuous with the curve of the left side of the diaphragm. On deep inspiration, this notch became wider and the projection of the other shadow above the diaphragm became more distinct. This shadow was apparently continuous with the stomach shadow. When the patient was placed on the right side, the shadow, projecting above the dia-

phragm, was continuous with the stomach shadow below the diaphragm, it was not continuous with the esophagus, the esophagus passing behind this shadow. The patient was transferred to the Presbyterian Hospital, still vomiting, where she was given physiologic sodium chlorid retention enemas.

Operation—Under ether anesthesia, a large S-shaped incision was made. About one half of the stomach was found to be herniated through a small opening of the diaphragm close to the esophagus. The stomach was pulled down, the hernia opening closed and the stomach sutured with catgut so as to cover the hernial opening and prevent the return of the stomach. The incision was closed without drainage. The patient died during the night of postoperative shock.

Necropsy Findings (Dr Hirsch)—These were papillary carcinoma of the splenic flexure of the colon, complete occlusion of the bowel, marked distention and hypertrophy of the proximal portion of the colon and of the ileum and jejunum, extensive submucous hemorrhages in the large and small bowel, a large amount of feces proximal to, and absence of feces distal to, the carcinoma of the colon, hernial sac above the diaphragm to the left of the esophagus, moderate fatty changes in the liver, arteriosclerotic myocardium, and scarring of the kidneys.

CASE 3—History—Mrs. L. O'C., aged 41, first entered the service of Dr. Sippy, complaining of vomiting, constipation, loss of weight and strength. Five years before, the patient had begun to have recurring attacks of "heartburn" coming on two to three hours after meals and associated with belching of sour material, coarse foods, vegetables and fruits made it worse. There were periods of several weeks' duration when she was entirely free from distress. During the last two years, the patient had been vomiting, at first only once a week, lately three or four times a week. Usually she vomited two to three hours after meals, sometimes at 1 or 2 a. m. Quarts of material were vomited. At one time, she vomited asparagus she had eaten seventeen hours before. She never vomited blood or "coffee-ground" material. There was no abdominal tenderness. She had lost 30 pounds in six months, having weighed 195 originally. She had used an enema for practically every bowel movement during the last two years.

Examination—The heart and lungs were negative. There was no abdominal tenderness. The stomach, distended with sodium bicarbonate, showed visible peristalsis.

Fluoroscopic Examination—This examination, made July 12, 1916, revealed small retention, a large stomach and very vigorous peristalsis, as many as three waves at one time. The antrum was closed off in all directions, uniformly. Occasionally, a small stream of barium could be seen passing through the duodenum. There was no duodenal cap.

Diagnosis and Treatment—Following a diagnosis of duodenal ulcer, the patient was put on "Sippy" management and left the hospital five weeks later, with the condition improved. She followed directions carefully at home and was all right during the first two or three months, but when she changed to two-hour intervals between feedings, she began to notice nausea and a tendency to "fill up." She aspirated herself several times a day, obtaining from 1 to 4 pints of thin, watery liquid at a time. The patient reentered the hospital six months after dismissal.

Fluoroscopic Examination—The colon was found behind the stomach and passed through the esophageal opening in the diaphragm. The colon lifted up the outlet of the stomach and portions of the duodenum adjacent to the stomach. Because the duodenum was fixed, malposition and traction on the duodenum probably caused the obstruction. Air could be seen in the colon above the diaphragm. Dr B W Sippy stated that there were "no adequate physical findings on auscultation and percussion to indicate anything abnormal." When the patient was questioned after the fluoroscopic examination, it was found that four or five years before she had fallen down the entire length of stairs, feet first, and had struck on her back. She had had some heartburn before the accident and more after it. She fainted. There had been no vomiting before the accident, but there had been some vomiting at intervals since the accident. Vomiting spells were followed by marked epigastric tenderness so that the patient could not wear a corset.

Operation—Under ether anesthesia, a large S-shaped incision was made on left side. When the peritoneum was opened the stomach appeared in the wound. The great omentum and transverse colon were found to be herniated into the left thoracic cavity through a diaphragmatic opening the size of a fist. The opening was around the esophageal hiatus. The omentum and colon were pulled back, and the diaphragmatic sac was closed with continuous catgut sutures. The tear in the omentum was closed with catgut. The incision was closed without drainage and the patient left the hospital in sixteen days, entirely recovered.

CASE 4—History—Mr R C D, aged 49, a freight handler entered the Presbyterian Hospital, on the service of Dr Sippy, complaining of distress and cramplike pain in the abdomen, tenderness in the epigastrium, nausea and vomiting, constipation, catharsis and pain in the left shoulder. Three years before, the patient had begun to experience distress and soreness in the left side of the abdomen, which came on shortly after eating. He belched considerably. There were periods from a few days to a week when he would feel all right. He also began having great difficulty with the bowels, he had to take a cathartic pill every night. The stools would usually be formed, but sometimes they were mushy or watery. During the last year he had used a cathartic pill and salines. The distress was located chiefly in the left side of the abdomen and epigastrium, and not in the right side at all. It was of a burning character and at times became so severe that the patient could not lie down. It was usually steady, but might be cramplike. In the chest, there was a feeling of fullness under the left ribs and sternum. Attacks of this pain lasted from two to five hours. There was no difficulty in swallowing. During the last year he had had pain in the left shoulder following the severe abdominal pain. Vomiting always gave relief from the epigastric and subscapular pain.

Examination—This was negative except that there was tenderness across the epigastrium. Respiratory mobility of the lower left lung border posteriorly, was not so good as on the right side, and the breath tones were muffled over the left anterior border.

The stomach was distended with soda and tartaric acid. Some pain was produced a few seconds after inflation. Coincident with the pain, marked rumbling and gurgling sounds were heard just below the left nipple by stethoscope. What appeared to be a great distention and stomach tympany could

be made out as high as the nipple in the midaxillary line, and there was obliteration of normal splenic dulness. The lower border of the stomach could not be definitely made out. No visible peristaltic waves were seen.

Fluoroscopic Examination—When barium was drunk, the shadow appeared on the left side of the chest, obscuring the heart shadow. The heart was displaced somewhat to the right. When the patient stood to complete the filling, the cardiac orifice was seen below the major part of the stomach as shown by the shadow of barium and the air space above. The colon was filled, with no evidence of obstruction. The transverse colon did not pass through the hernial opening in the diaphragm.

Operation and Result—Under ether anesthesia, a left side S-shaped incision was made, exposing the stomach. The greater curvature portion of the fundus and antrum with its omentum was found in a peritoneal sac extending through the diaphragm into the mediastinum, the opening being just to the left of the hiatus esophagus. The stomach was delivered from its sac. Adherent omentum was separated. After invaginating the peritoneal sac, catgut sutures were inserted to obliterate the sac and hole. Then the fundus of the stomach was sewed by its greater curvature to the parietal peritoneum. The herniated stomach was rough and in places scarred by fibrous tissue. Two cigaret drains were inserted, but were removed in forty-eight hours. The wound healed by first intention and the patient left the hospital in twenty days cured, as indicated by subsequent fluoroscopic examination.

ESOPHAGEAL DIVERTICULA

E S JUDD, M D,
ROCHESTER, MINN

Although diverticulum of the esophagus occurs more often than we are led to believe from the number of cases reported, it is a comparatively rare condition. Operations on nearly 200 patients with esophageal diverticula, including those in our series, have been reported. Diverticula which do not produce symptoms apparently may occur at almost any point in the esophagus and may be caused by an increase in the intra-esophageal pressure or, more likely, by some tractive force from the outside. Such irregular and small diverticula are often reported in necropsy examinations, but seldom make themselves known during life.

The two common types of esophageal diverticula are the pressure and the traction diverticula. The traction diverticulum commonly occurs in the thoracic part of the esophagus, while the pressure diverticulum is nearly always formed in the cervical region. The traction diverticula are so called because many of them are formed demonstrably by the pulling out of the walls of the esophagus by some inflammatory adhesion. Most often the adhesions have been shown to have resulted from a cicatrix from the suppuration of a lymph node. The traction diverticula are usually multiple and seldom attain an appreciable size or produce symptoms. The apex of the pouch is usually higher than its point of entrance into the esophagus, and, therefore, no opportunity is afforded for food to accumulate, nor is there a tendency for the sac to increase in size. Occasionally, food particles lodge in the pouch, the sac enlarges, due to the pressure from the inside, and in this manner the traction diverticulum is converted into a traction-pressure diverticulum. It is estimated that this conversion takes place in about 7 per cent of traction diverticula. We have seen two cases of traction-pressure diverticula of the esophagus. At least the patients had good sized diverticular sacs at the lower end of the esophagus. In a previous paper,¹ I reported one of these cases. In both there were symptoms which might be due to diverticula. In the second case, the diverticulum was associated with cardiospasm, this patient was completely relieved by dilating the cardia.

It has not been demonstrated whether a diverticulum in the thoracic part of the esophagus is a true diverticulum in which the sac is com-

1 Judd, E S Esophageal Diverticula, Surg, Gynec & Obst 27 135
(Aug) 1918

posed of all coats of the esophagus, or whether it is really a hernia of the mucosa and submucosa through a separation in the musculature. Undoubtedly, the traction diverticulum includes all the layers of the esophagus. Attention has been called to an area in the thoracic esophagus, however, in which the support outside the esophagus is lacking. This is the area in which diverticula are frequently seen (Brosch² and LeCount³). It is possible that the sac in these cases is formed as a hernia of the mucosa and submucosa as is the case in the pharyngo-esophageal diverticulum, and a pressure diverticulum thus occurs in the lower part of the esophagus.

Zenker and Ziemssen,⁴ in 1877, first described the pressure diverticulum, and since that time it has been known as the Zenker pharyngo-esophageal diverticulum. This diverticulum always occurs at the same point in the wall of the esophagus, known as the pharyngo-esophageal dimple, which is just behind the cricoid cartilage on the posterior wall at its juncture with the pharynx (Fig 1). This weakness in the wall of the esophagus is the result of the arrangement of the musculature of the lower end of the pharynx and the upper end of the esophagus. During the act of swallowing, considerable pressure may be exerted from the inner part of the esophagus, and it is quite natural that the inner coats might be gradually forced through a chink in the outer coats and in this way form a simple pouch. The pouch would tend to increase in size each time the intra-esophageal pressure increased until the pouch became large enough to hold accumulated food and mucus from the esophagus. The accumulated material would also tend to increase the size of the pouch. Diverticula throughout the gastrointestinal tract are not uncommon. They occur quite often in the duodenum and other parts of the small intestine, especially as a Meckel's diverticulum. Diverticulitis, as it occurs in the sigmoid and other parts of the intestine, is common also, but in all such cases the sac of the diverticulum is composed of all the coats, the mucosa, submucosa, muscular layers, and peritoneum, which make up the viscus from which the diverticulum originates. This is not true of the pharyngo-esophageal diverticulum, as its sac contains only the mucous membrane and submucosa. Occasionally, there may be a band of muscle fibers extending across the sac, but muscle tissue is not a part of the sac wall. So far as I know, hernia of the inner layers of a

2 Brosch, A. Epibronchiale Pulsions-Divertikel. *Arch f path Anat* **162** 22, 1900, Zur Anatomie und Pathogenese der Vorderwand-Divertikel des Esophagus, *Arch f path Anat* **176** 328, 1904.

3 LeCount, E. R. Epibronchial Pulsion Diverticula of the Esophagus, *Tr Chicago Path Soc.* **10** 35, 1915.

4 Zenker, F. A. and Ziemssen, H. Krankheiten des Esophagus, *Ziemssen's Handbuch der speciellen Pathologie und Therapie* Leipzig **7** 208 1874.

viscus through a separation in the outer layers to form a diverticular pouch occurs in only one other region, and that is in the urinary bladder. The diverticular sac of an esophageal diverticulum and the sac of a bladder diverticulum are formed in identically the same manner. The sac of a diverticulum of the bladder is also composed largely of mucosa and submucosa, and contains very little if any muscular tissue.

From a review of the histories of our cases, we were unable to obtain any other clue to the etiology than the weakness in the wall of

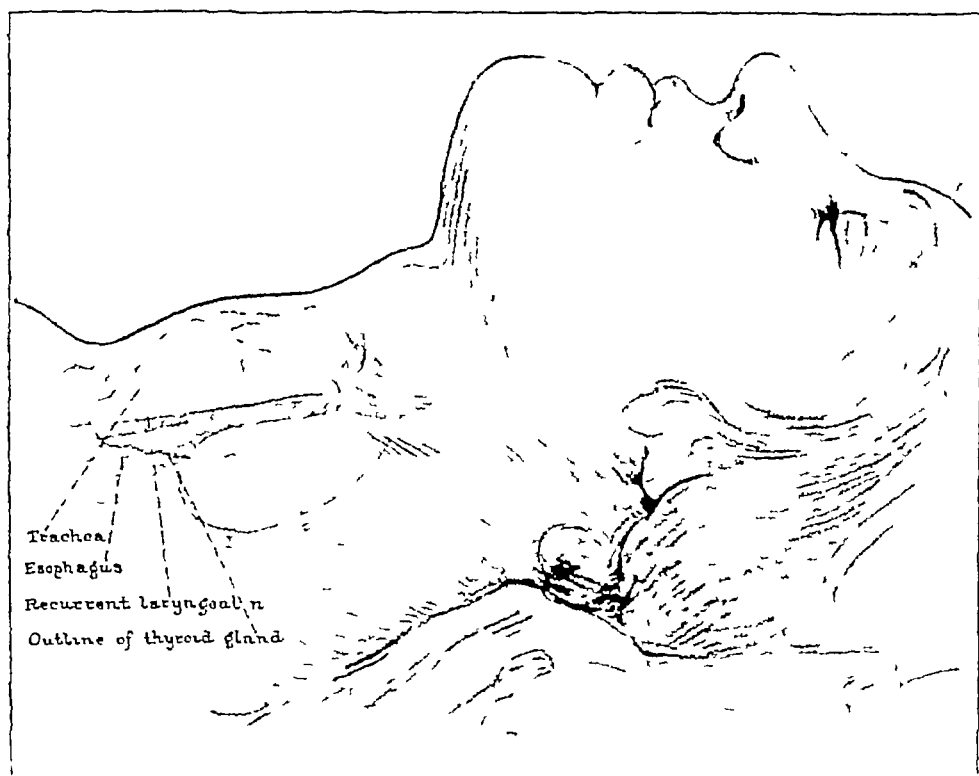


Fig 1—The usual position of the diverticulum on the left side of the neck behind the esophagus

the upper end of the esophagus. There had been no history of trauma or any evidence of anything unusual in mastication or deglutition. The first symptom noticed in nearly all cases was dryness in the throat and a gradually increasing difficulty in swallowing. The sensation of some foreign material in the throat was often mentioned. These symptoms led to accumulations of mucus, and later undigested particles of food were raised. Dysphagia and a gurgling noise in the throat are mentioned as an early symptom by nearly all patients. As the sac increases in size, the patient has the sensation of pressure and often the esophagus closes, so that there is almost a complete stenosis of the

lumen. This sometimes leads to the diagnosis of carcinoma or stricture for which not a few of these patients have been treated. None of our patients had had symptoms during early life that would indicate this condition. The symptoms very rarely appeared until the patients were 45, in our series of fifty-four cases, the average age at the time of operation was about 55, and the symptoms had been present on an average of about six years. If the sac is large and filled, it can usually be felt and seen in the neck. Although the communication of the sac with the esophagus is in the midline, the sac itself is more often on the left side and sometimes when it cannot be seen or felt, its contents



Fig. 2—Type of esophageal diverticulum

may be expressed by pressure with the fingers on the left side of the neck. The size of the sac varies greatly. In some instances it is just large enough to be made out, and in other instances it is so large that it occupies the greater portion of the upper mediastinal space. Usually the symptoms are proportional to the size of the sack, although sometimes a small sac is placed so as to make more trouble than a larger sac.

DIAGNOSIS

Before the development of roentgen ray and esophagoscopic examinations it was often quite difficult to make an accurate diagnosis in

cases of esophageal diverticula and many complicated and inaccurate tests were carried out. Now an accurate diagnosis can be made by either one or both of these methods. If the histories suggest a possibility of the condition, it is our custom to have a roentgenologic examination made of this region after the patient has swallowed a bismuth mixture, and the diverticulum is revealed in practically every



Fig 3—Type of esophageal diverticulum

case (Figs 2, 3 and 4). After this an esophagoscopic examination is made to rule out the possibility of other lesions, such as a stricture below the diverticular opening, or any other condition in the lower end of the esophagus. The examination, as carried out in the clinic by Carman, Plummer and Vinson, of these cases of lesions of the esophagus, which were not so well examined or understood a few

years ago, now places them among our most satisfactory cases. The improvement in the treatment is very largely due to knowledge obtained through these examinations.

In the differential diagnosis, dilatations of the esophagus must be excluded, they are usually due to spasm at the cardia (Fig 5) or stricture of the esophagus due to scar, or, as in one case in our series,

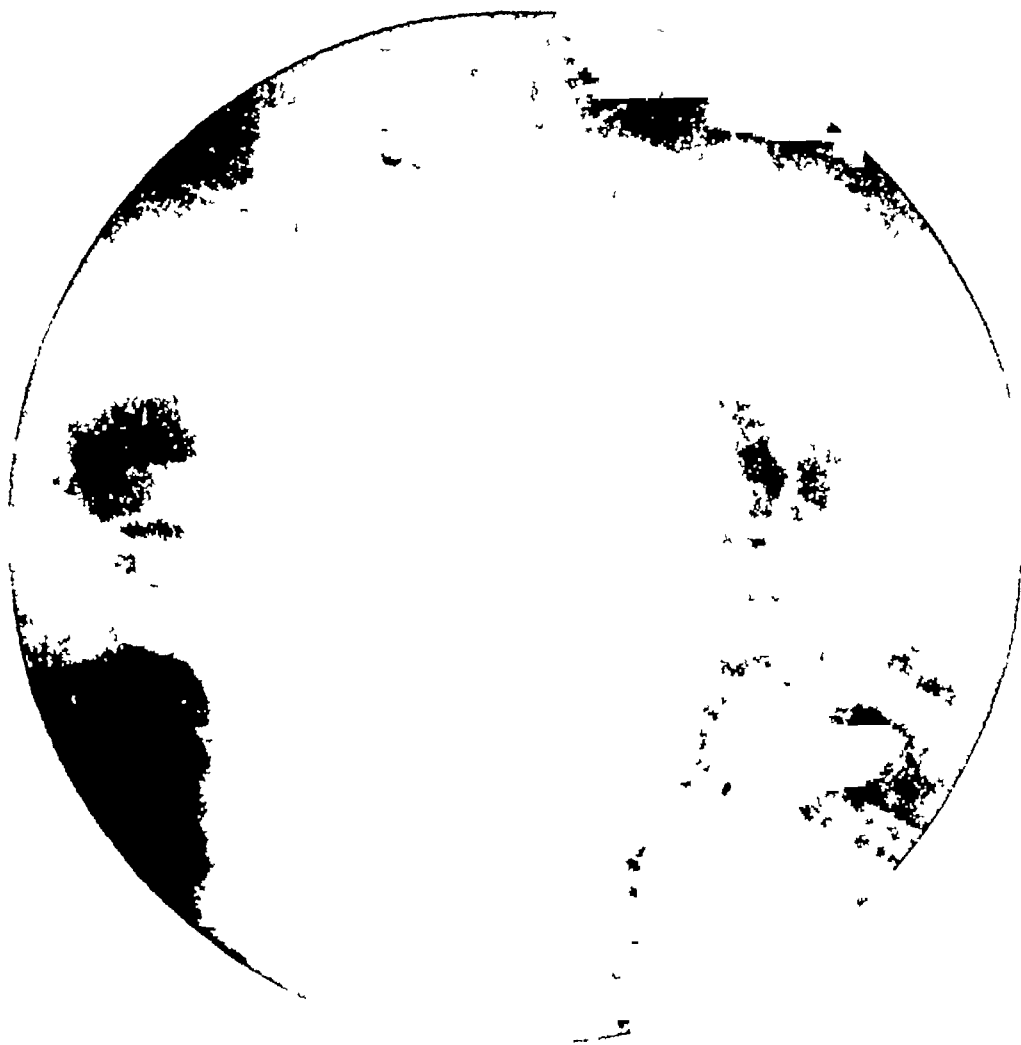


Fig 4—Type of esophageal diverticulum

stricture apparently due to a congenital diaphragm. In this case (Fig 6), the roentgenogram more closely resembled the picture of a diverticulum than any other we have seen, and yet the age of the patient, 20 months, almost ruled out the possibility of a diverticulum. From the roentgen-ray examination alone it seems to me, it would be difficult to decide that the lesion was not a diverticulum, particularly since the pouch occurred in the location that a diverticulum would

assume The methods used by Plummer and Vinson however, enabled them, by one dilatation, to cause the pouching entirely to disappear In this case, in which a pouch had formed above a stricture, the sac consisted in a dilatation of the esophagus, and not of a diverticulum

The symptoms of stricture caused by carcinoma are often similar to those of diverticulum These conditions occur at the same age, but



Fig 5 (Case 304841) —Cardiospasm with diffuse dilatation of the esophagus

the roentgen ray and the esophagoscope clearly differentiate the two (Fig 7)

TREATMENT

The treatment of esophageal diverticula is surgical In some of the cases in which the diverticular sac is small, the symptoms may be relieved by dilating the esophagus, and the patients can be kept fairly

comfortable by repeating the dilatations at intervals (Mixer⁵) In most cases, however, there is a tendency for the sac to increase in size until it is so large and deforms the esophagus so much that it stops almost all, or all, of the food, and extreme emaciation results Some of the patients come for treatment in a starved condition, and require forced feeding before any treatment for the diverticulum can be under-



Fig 6 (Case 311960)—Stricture of the upper esophagus probably congenital, in a child aged 20 months Roentgenogram identical to that of a pharyngo-esophageal diverticulum

taken Sometimes they learn to feed themselves with a tube, and in rare instances it is necessary to form a gastrostomy for feeding before anything further can be done The early operations for the removal

⁵ Mixer, S I Congenital Esophageal Pouch Excision Immediate Suture of Esophagus Recovery Tr Am Surg Assn 8 357, 1895

of the diverticular sac were attended with a high mortality. This mortality was due to infection which occurred at the site of the operation and extended downward into the mediastinum.

Three types of operation may be employed. In the first, described by Girard⁶ and Bevan,⁷ the sac is dissected from its bed behind the esophagus and in front of the vertebra. After the neck of the sac



Fig. 7 (Case 283977) —Carcinoma of the middle third of the esophagus

has been completely freed from the surrounding tissues, purse-string sutures and plicating stitches are placed so that when the sac is tucked into the esophagus and the stitches are tightened, the sac will be per-

6 Girard, C. Du traitement des diverticules de l'oesophage, *Cong. franç. chir.* 10:392, 1896.

7 Bevan, A. D. Pulsion Diverticulum of the Esophagus, Cure by the Sippy-Bevan Operation, *Surg. Clinics, Chicago* 1:449 (June) 1917.

manently held in the lumen of the esophagus where it atrophies or possibly sloughs off. This method of operating is applicable in cases in which the sac is small. We have employed it several times, and with the exception of one case in which there was a small recurrence, it has been satisfactory.

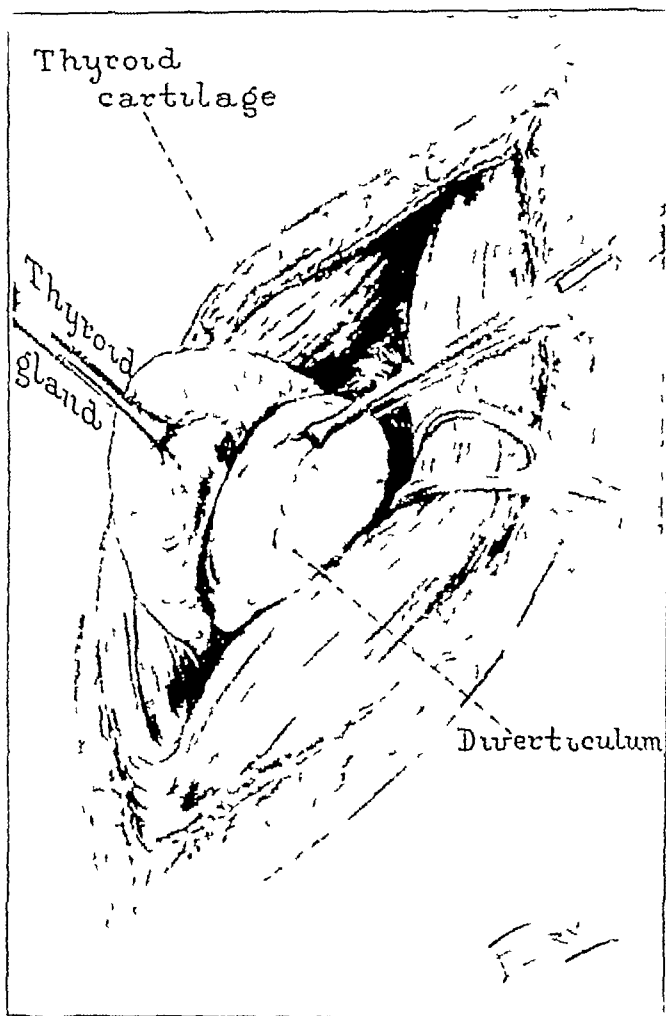


Fig 8—The thyroid gland pulled aside to bring the diverticulum into view

The second method is the one formerly used a great deal, that is, the complete excision of the sac and suture in one stage. This operation is undoubtedly the ideal one and is satisfactory in many cases, but in our experience, in the occasional case there is a certain amount of leaking from the suture line before the pocket behind has become lined with a granulation barrier and in some cases the result is serious.

The third method is the two-stage operation suggested by I. B.

Murphy⁸ and C H Mayo⁹ The first stage consists in freeing the sac in the usual manner from the surrounding tissues and dissecting the mucous membrane 1 to 2 cm from the musculature of the esophagus (Figs 8 and 9) At this point the neck of the sac is caught to the sternomastoid or even to the platysma muscle with a few interrupted catgut sutures, the wound in the neck is closed around the neck of the

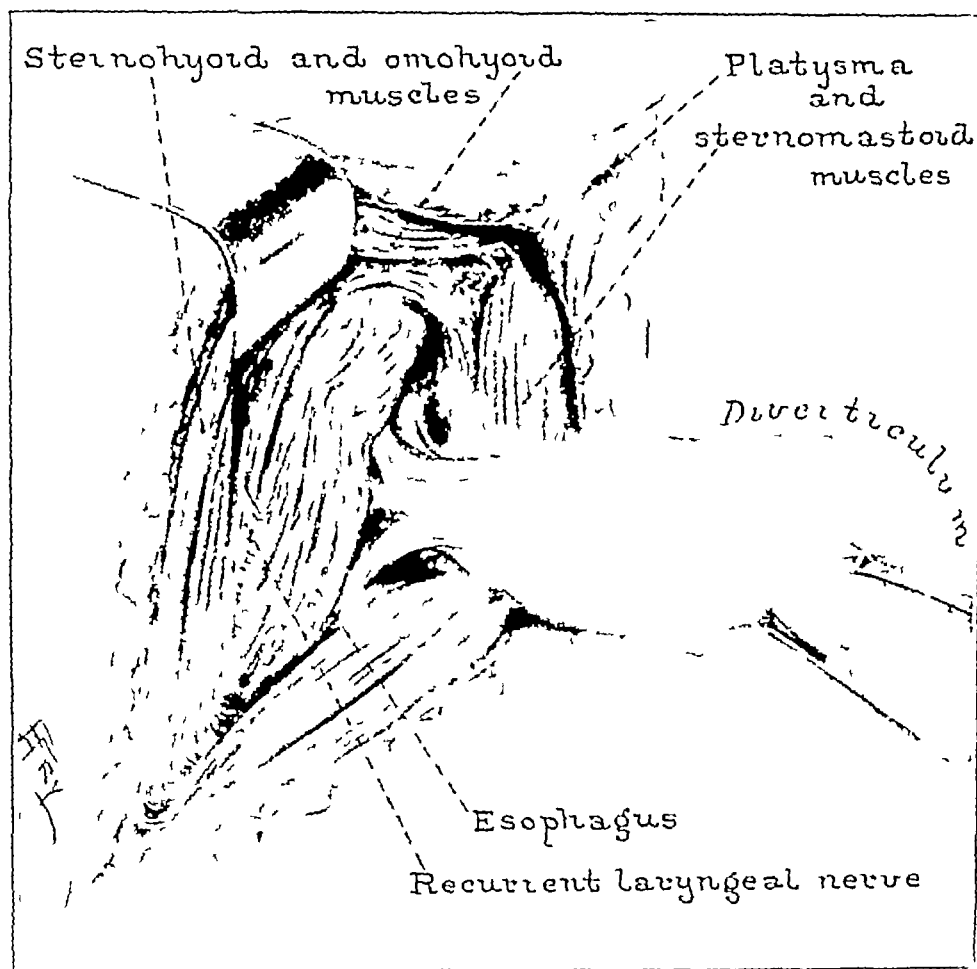


Fig 9—The diverticulum freed and the neck and the attachment to the esophagus exposed

sac, and the entire sac is allowed to prolapse from the wound Neither the esophagus nor the diverticular sac is open so that the surrounding tissues and spaces are not exposed to any infection By the removal of the sac from its place behind the esophagus, the deformity in the

⁸ Murphy, J B Diverticulum of the Esophagus, Conservative Treatment Surg Clinics, Chicago 5 391, 1916

⁹ Mayo, C H Diagnosis and Surgical Treatment of Esophageal Diverticula, Report of Eight Cases, Ann Surg 51 812, 1910

esophagus is corrected and immediately afterward the patient swallows without difficulty. The sac is left in this position for ten or twelve days, during which time the patient is able to be up and around, and can leave the hospital if he wishes (Fig 10). Murphy advised twisting the neck of the sac before suturing it to the muscles. In some cases we have followed this plan, although in a few the distal part of the sac sloughed as a result of reduced circulation. The only difference in these cases was that small esophageal fistulas persisted for a short time, and for this reason I believe that it is better not to



Fig 10 (Case 313455)—Patient three days after first stage of two-stage operation

twist the neck of the sac. Usually at the end of ten or twelve days, the patient returns to the operating room. At this time there is a complete barrier of granulation tissues which separates the pocket in the neck and the mediastinum. In the second stage it is not necessary to use an anesthetic of any kind. In some instances it may be well to inject the neck of the sac with procain before excising it. The neck of the sac is again freed, the sac excised, and the opening in the esophagus and the wound in the neck are closed (Fig 11). In some instances a small fistula forms although it always heals completely within a short time. In one case in which the diverticulum was very large and in which there had been considerable deformity of the esophagus,

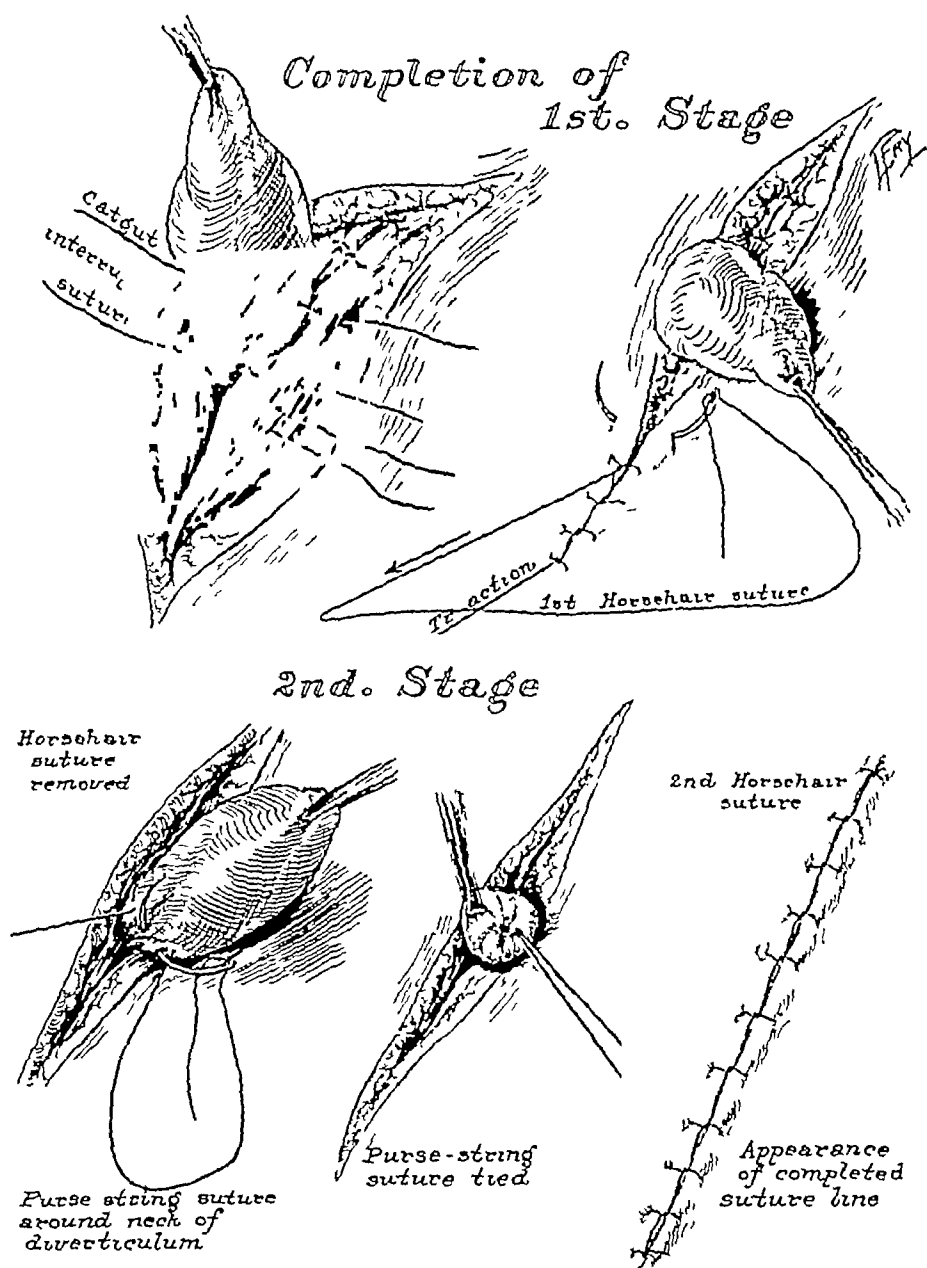


Fig 11—Prolapse of diverticulum from the wound at the end of the first stage of the operation Freeing and excision of the sac at the second stage

the fistula persisted for a number of weeks and it was necessary to make a secondary closure. In all other cases the wound healed primarily or within a few days after the second-stage operation (Fig 12)

The two-stage procedure simplifies the operation greatly and is infinitely safer than the complete excision of the sac in one stage, the inconvenience to the patient and the time and suffering are also less than they would be if complete excision were performed in one stage

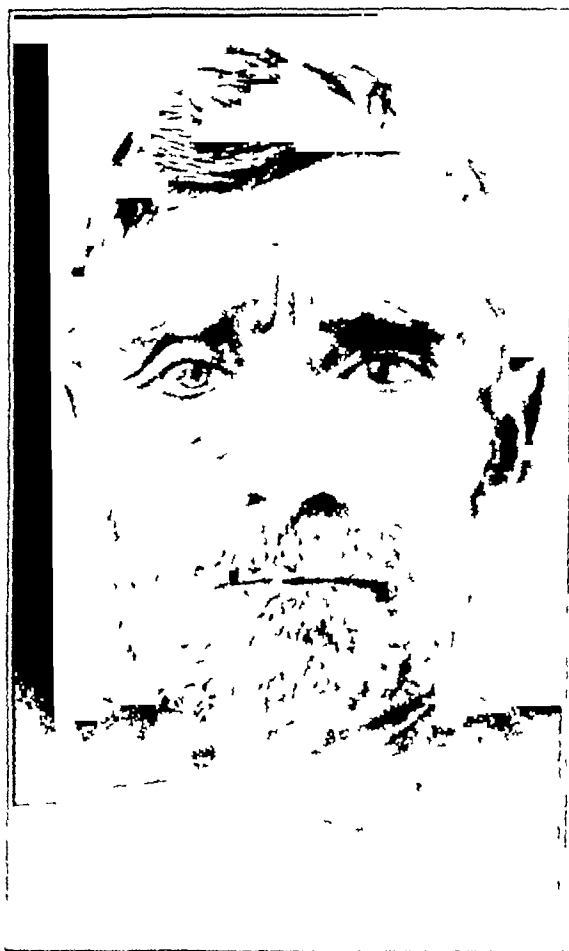


Fig 12 (Case 313455) —Patient shown in Figure 10. Wound healed and in good condition ten days after removal of diverticulum at second stage of two-stage operation

In many of our early cases the one-stage operation was performed but the two-stage operation is so safe I believe that it should be employed in nearly all instances. If infection occurs following the one-stage operation, it results fatally in many cases. Of late I have used the two-stage operation in cases in which the sac was small and it has been satisfactory.

OPERATIVE RESULTS

We have operated in fifty-four cases of esophageal diverticula with three deaths, two are included in my former report of thirty-five cases. Two of the patients died following a one-stage operation, the third following the first stage of a two-stage operation.

The ultimate functional results have been very satisfactory. One patient was operated on for recurrence, and in one or two cases a sound has been passed because the esophagus seemed too small, but in no instance has a stricture developed.

MANAGEMENT OF DIRECT INGUINAL HERNIA

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The problem of inguinal hernia has resolved itself into the management of the direct variety. This statement is based on the fact that all surgeons agree that in indirect or oblique hernia the results following operation are excellent, provided it is performed properly and according to one of the approved methods. No such claim can be made for the operative results in direct hernia, nor can it be said that we have a standardized operation for this condition. Many surgeons recognize the futility of the usual technic for indirect hernia when applied to the direct type, and various modifications of recognized procedures have been devised in the effort to correct the inherent anatomic defects that give rise to this form of rupture. Up to the present time, however, none of these modifications have proved satisfactory in all cases, and I, for one, have reached the conclusion that a certain number of direct hernias cannot be cured by operation.

The difficulty lies in selecting the cases suitable for operative treatment. It is not an uncommon experience in what seemed to be a most favorable case to have the patient return with an early recurrence, and on the other hand, of having a most unfavorable case result in a permanent cure. As a rule, however, the patients in whom recurrence is almost sure to take place belong to a definite group. They are usually thin men with poorly developed muscles in both lower quadrants. Coughing or strain produces a general bulge extending from above the anterior superior spine over to the margin of the rectus, and down to the external ring, with a more or less marked hernial protrusion about the middle of the inguinal canal or at the ring. Palpation of the inguinal region may reveal a positive separation in the external oblique aponeurosis, or by invagination of the scrotum, one or more fingers may be inserted into the external ring and passed directly backward, revealing almost complete absence of the conjoined tendon. In other words, not only is the roof to the inguinal canal weak but the floor is formed principally of transversalis fascia and peritoneum.

To the foregoing group may be added certain persons who have accumulated considerable fat over the lower abdomen. This fat obscures the condition of the underlying muscles and also interferes with proper palpation. The unfavorable outlook in this class of cases may not be recognized until after the patient comes to operation. The man with weak muscles and a small bulge at the lower part of the

was accepted by the army after he had undergone a so-called radical cure operation for hernia, without especial attention to the type of hernia, length of time following operation, or to the surgeon by whom it was performed. Later, all men between the ages of 21 and 31 with hernia were accepted by the army. If the time between examination and date of call permitted, these men could go where or to whom they chose for operation, if not, they were forced to be operated on immediately after reaching camp. Finally, in the last draft no man with

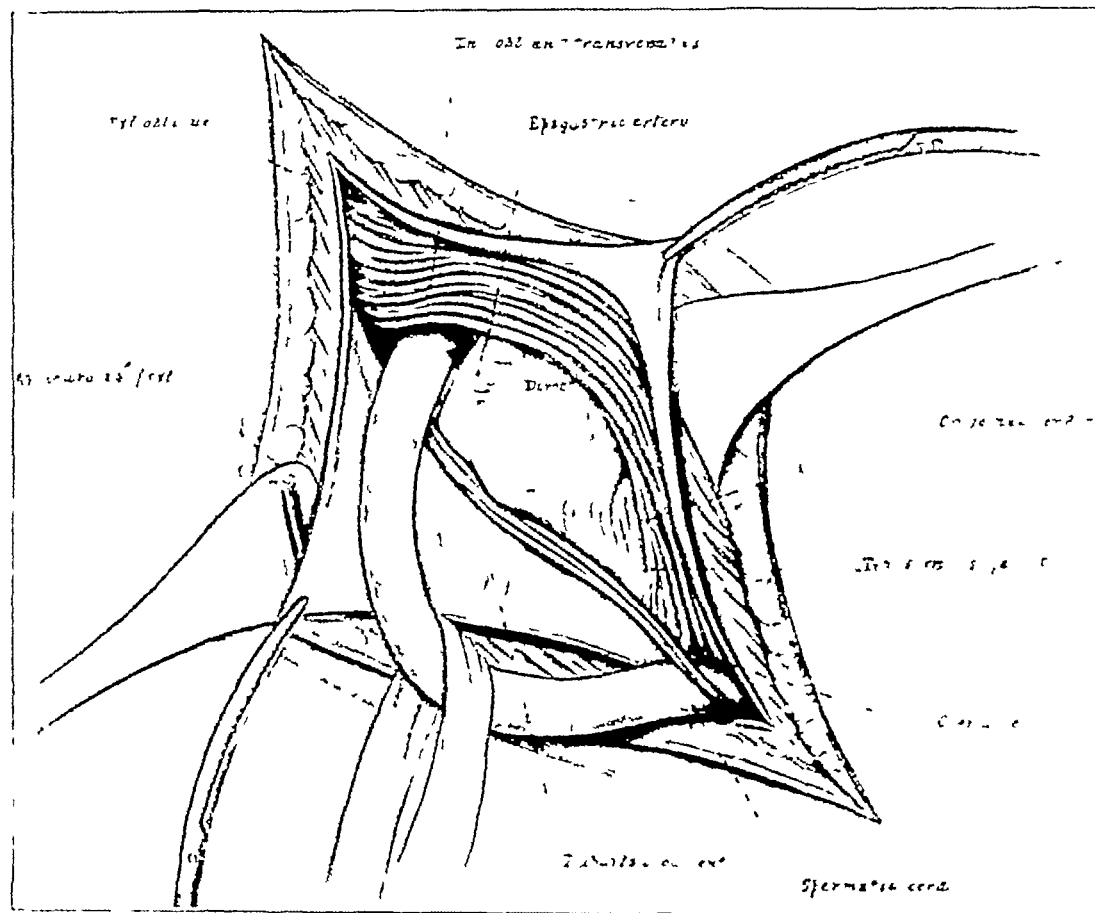


Fig 2—Direct inguinal hernia

hernia was accepted for full military duty either before or after being operated on. From these changes in the regulations, it is quite evident that the results following herniotomy were not so satisfactory as had been anticipated. While some of the recurrences in soldiers may have been the result of poor technique, I venture to state that the great majority occurred in hernia of the direct variety, and that a good percentage of these were of the type which should never have been operated on. Aside from the disappointment to the surgeon in having recurrence take place the patient himself deserves more consideration,

for, after all, it is he who has to suffer the consequences. We often console ourselves with the thought that even if the hernia does return it will not be so bad or so hard to control by a truss as it was before operation. When the loss of time, the danger of going through an operative procedure, even though very slight, and the occasional risk of complications are taken into consideration, are we quite justified in operating except for good reason in this type of case when we know from experience that the result is likely to be unsatisfactory?

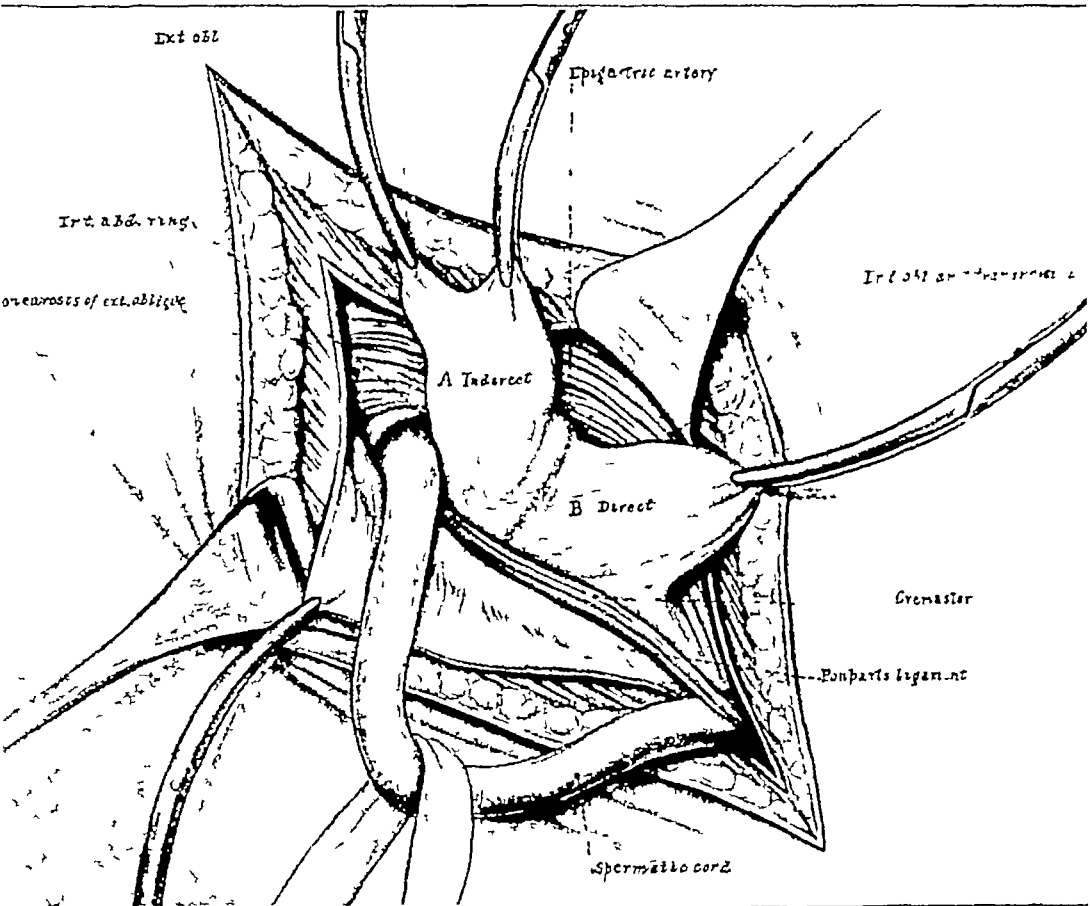


Fig 3—Combined direct and indirect hernia—"pantaloonsac"

ANATOMIC CONSIDERATIONS

A correct knowledge and clear understanding of the anatomy of the inguinal region (Fig 1) is necessary in order to obtain satisfactory results from the operative treatment of hernia. Without this knowledge there is little satisfaction to the surgeon, and a grave injustice may be done the patient. Paradoxical as it may seem, the wonderful results obtained in recent years following operation in the indirect inguinal hernia group, which comprises more than 90 per cent of all

hernias, is largely responsible for the number of failures in the cases of direct hernia. The explanation is that many surgeons have come to look on the hernia operation as of almost minor importance, and pass these patients along to young assistants or house surgeons without proper supervision, with the result that if the anatomy or the arrangement of the sac is unusual, the operation is likely to prove a failure.

For the purposes of this paper, I shall speak of the inguinal region as that triangular part of the lower abdominal wall bounded

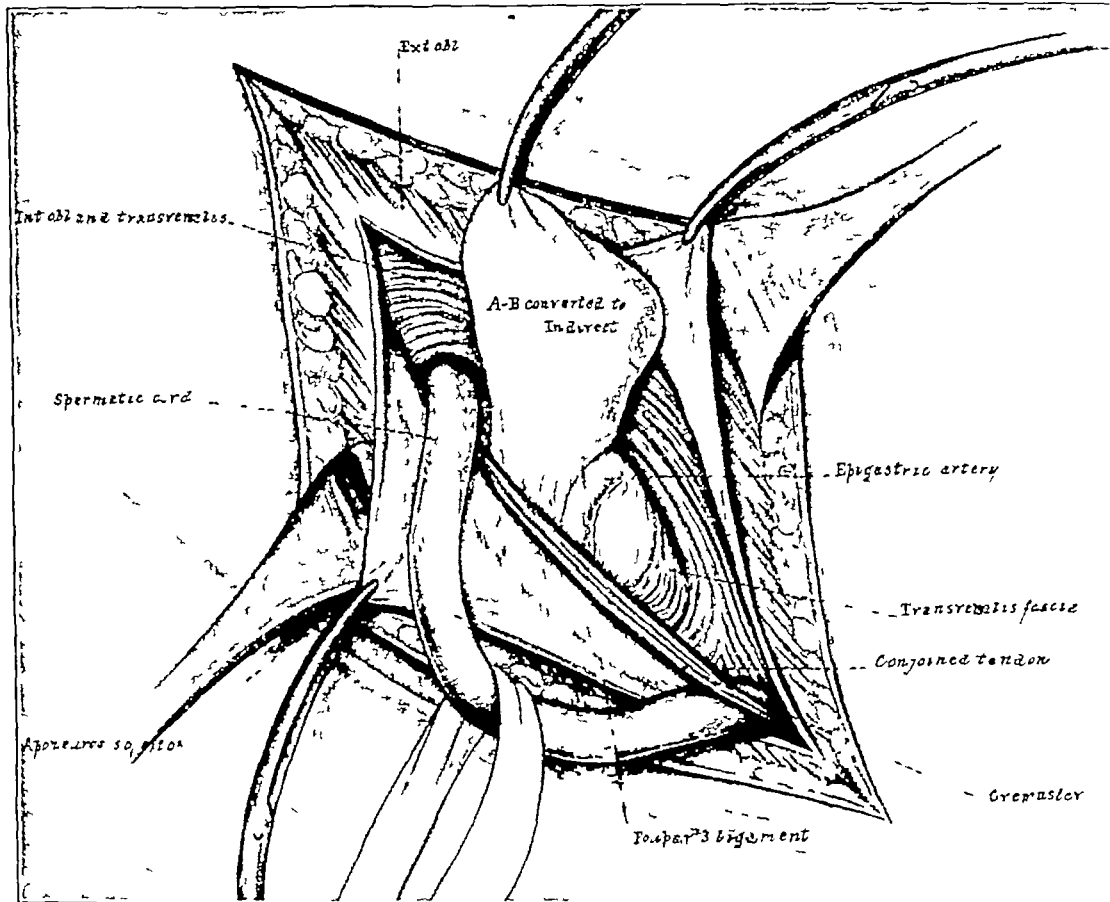


Fig 4—Combined sac converted into indirect hernia

below and to the outer side by Poupart's ligament, internally by the margin of the rectus, and above by a horizontal line extending from the anterior superior spine to the rectus muscle. The structures to be studied in the dissection of this area are the external oblique, internal oblique and transversalis muscles, including the cremaster muscle, the rectus muscle and its sheath, the conjoined tendon and transversalis fascia, also, the iliohypogastric and ilio-inguinal nerves, — and the deep epigastric artery.

The external oblique muscle, the fibers of which run down and in, may be referred to as the roof of the triangle. It is usually a firm aponeurotic structure extending as Poupart's ligament from the anterior superior spine to the pubic bone on the outer side, and to the linea alba on the inner. It presents at its lower inner portion an opening known as the external abdominal ring, which should normally admit the tip of the finger. The portions of the internal oblique and transversalis muscles encountered in the dissection arise from the

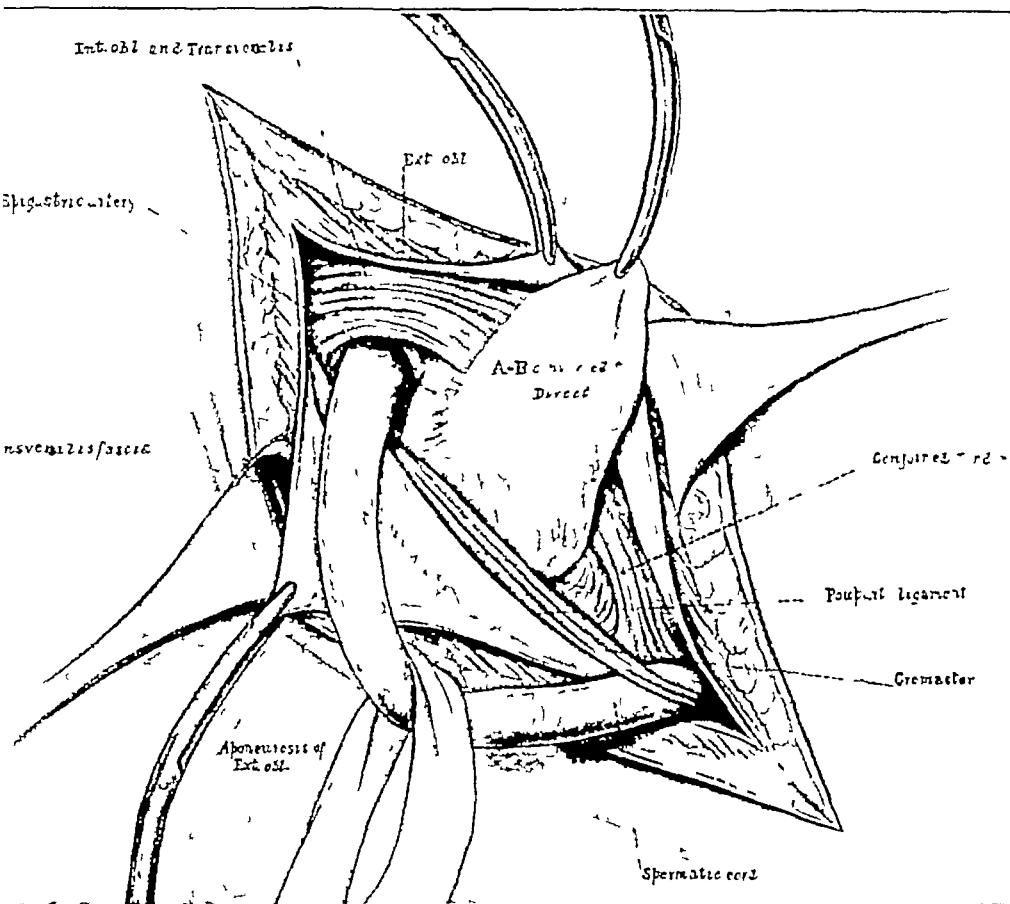


Fig 5—Combined sac converted into direct hernia

outer half to the outer third of Poupart's ligament. The former usually appears as a well-developed muscle arching down and in, completely overlapping the latter. The two blend into a common aponeurosis, which becomes part of the anterior sheath of the rectus in its lower fourth and is continued down to be inserted into the pubic crest and pectineal line—the latter portion forming the conjoint tendon. This tendon, extending laterally from the margin of the rectus muscle, lies just behind the external ring and in front of the

transversalis fascia Its thickness and width vary in different persons, but when well developed it is of considerable value in the prevention of direct hernia The cremaster, a thin layer of muscle fiber surrounding completely or in part the spermatic cord, has its origin at the lower margin of the internal oblique

The transversalis fascia—a fairly thick fibro-aponeurotic structure—may be said to form the floor of this triangular area The inner portion of this fascia is composed of more or less vertical fibers

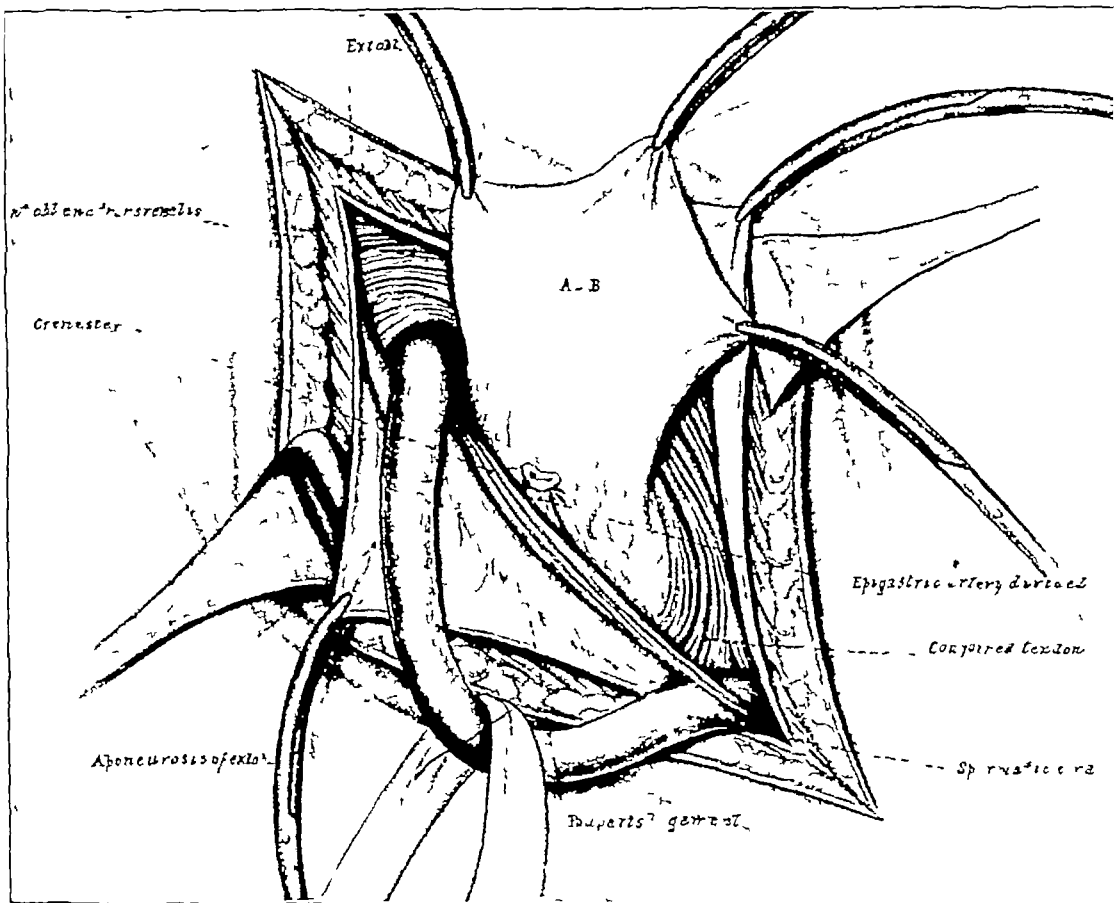


Fig 6—Combined sac converted into single sac by dividing epigastric artery

of considerable strength, the outer is made up of arching fibers through which the cord passes, forming the internal ring The middle portion, lying just below and internal to the deep epigastric artery, is the thinnest part of the fascia, and constitutes the weakest point in the floor It is through this weak middle part that the great majority of direct hernias occur

The deep epigastric artery—a branch of the external iliac—lies between the transversalis fascia and peritoneum, and runs on a line

from the middle of Poupart's ligament to the umbilicus. This artery forms the lower boundary of the internal ring, and is the most important landmark in this region, as the variety of a given hernia is determined by the relation of the neck of its sac to this vessel. The ilio-hypogastric and ilio-inguinal nerves—the former running along the anterior surface of the internal oblique to the margin of the rectus muscle, and the latter through the inguinal canal to the external ring—are both sensory in this location, but should be preserved. The inguinal canal, about $1\frac{1}{2}$ inches in length, occupies the lower

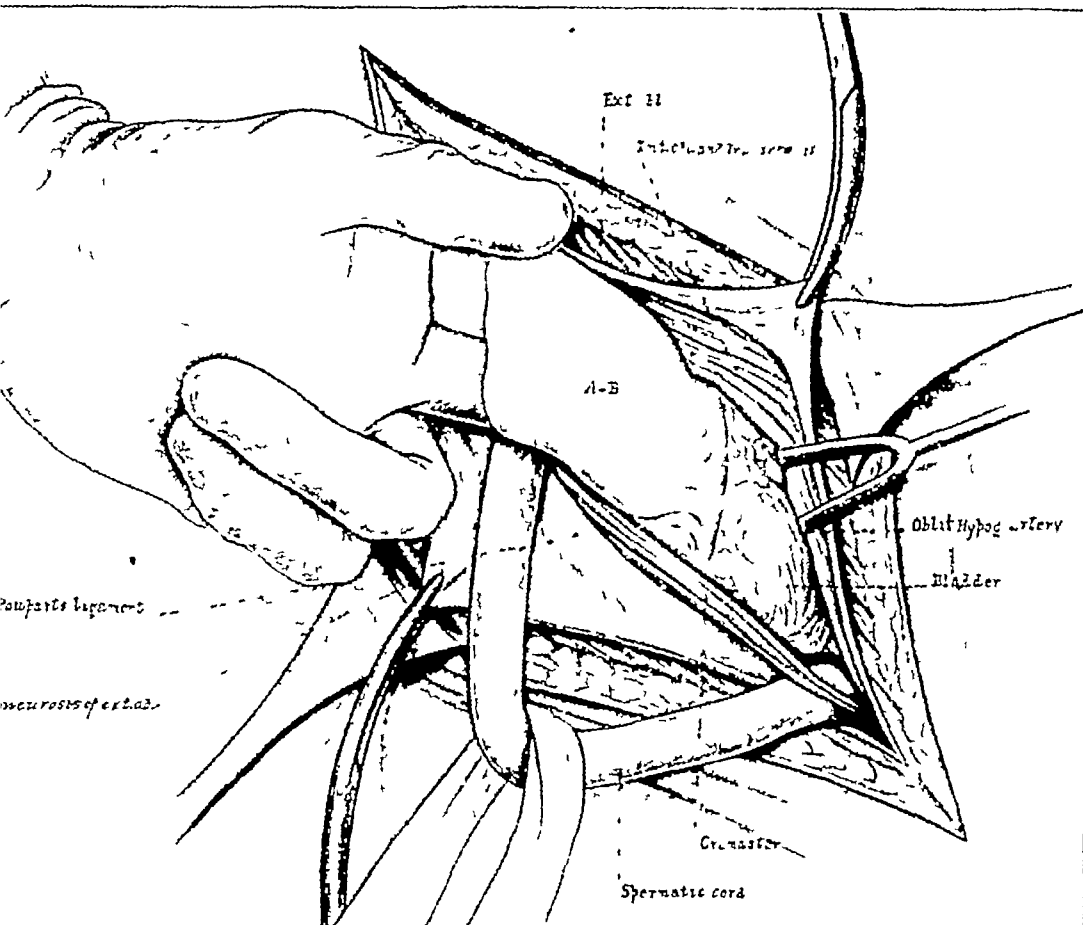


Fig 7—Sac opened showing peritoneal fat and bladder

outer part of this area, and runs down and in from the internal abdominal ring to the external ring at the pubic spine. It is occupied by the cord in the male, and round ligament in the female. The sacs of all hernias situated in this region bear a definite relation to this canal. The oblique or indirect hernias enter it at the internal ring and when complete traverse its entire course. The usual form of direct hernia, forcing its way through the transversalis fascia, enters

the canal at some point below the deep epigastric artery and appears at the external ring or not, depending on the size of the sac

Direct hernias constitute about 10 per cent of all primary inguinal hernias. On the other hand, considerably more than 50 per cent of secondary or recurrent inguinal hernias are of this variety. This large proportion of direct recurrences indicates either that the usual operation for this type of hernia is inadequate or that the primary hernia existed as a combined direct and indirect hernia, and the direct por-

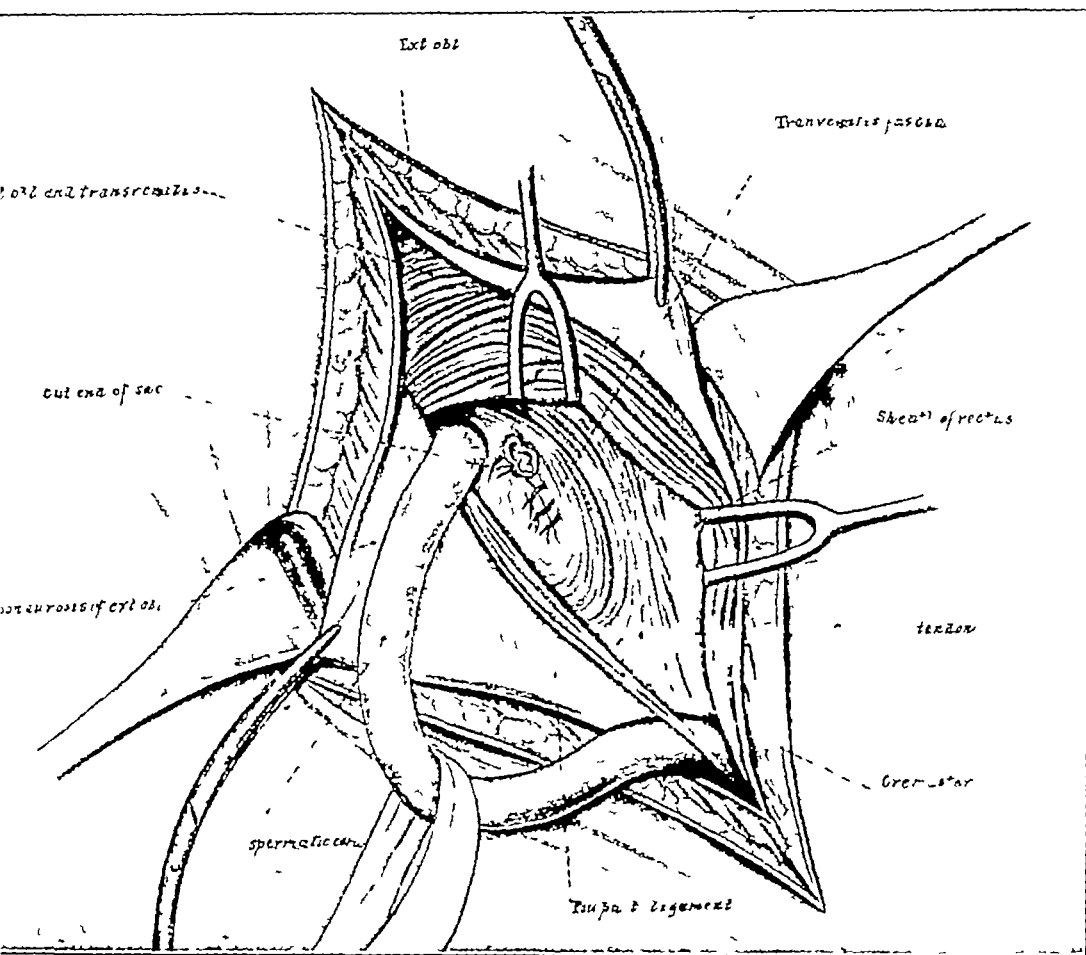


Fig 8—Neck of sac closed

tion of the sac was overlooked or the cases were improperly selected. The typical form of direct hernia (Fig 2) appears just below the deep epigastric artery through the weak middle portion of the transversalis fascia, and has, besides peritoneum, properitoneal fat and fascia, the cremaster muscle as a covering. However, not infrequently the cremaster with the cord lies entirely to the outer side of the sac. The combined direct and indirect hernia—the so-called pantaloon

sac—one portion of which appears above the deep epigastric artery and the other below (Fig 3), occurs perhaps half as frequently as the typical form. In this type either sac may constitute the major portion of the hernia, or the two may be of equal size. Rarely a direct protrusion occurs through the lower thick segment of the transversalis fascia some distance below the epigastric artery, and at times the sac may be divided into two portions by a band of fascia. An entirely different form of hernia, erroneously classed as direct inguinal, is occasionally found in the lower inner portion of this region (Fig 16). It appears in the linea semilunaris just above the pubic bone, and is very probably due to properitoneal fat working its way through one of the perivascular spaces. The peritoneum is dragged along with the fat, and the protrusion occurs between the margin of the rectus and the conjoined tendon, or pushes the latter structure ahead of it as one of its coverings. This hernia, usually small, although it may become of considerable proportions, resembles to a marked degree the femoral type in that it is globular in shape, contains much peritoneal fat, and has a narrow neck with sharp margins. The location of this protrusion is the only reason that can be given for grouping it under the general heading of direct hernia, as in no way does it conform to the essential requirements necessary for such classification. Hernia of the linea semilunaris may exist coincidentally with direct or indirect hernia, and may also occur at other points in the linea semilunaris. These protrusions are similar in nature to the epigastric hernia situated at or near the median line.

CAUSES, SYMPTOMS AND DIAGNOSIS OF DIRECT HERNIA

Direct hernia occurs most often in men between the ages of 25 and 45. It is occasionally seen in younger persons, and has even been reported in children. It is rare in women. Poorly developed or deficient musculature in the lower half of the abdominal wall may be said to be the underlying cause in practically every instance. Many of these patients have a narrow pelvis, with Poupart's ligament and the fibers of the external oblique muscle taking an almost vertical course. The portion of the internal oblique and transversalis muscles arising from Poupart's ligament, which usually consists of heavy muscular fibers extending well down over the internal ring and upper part of the inguinal canal, may be replaced by a thinned aponeurotic layer with a short muscular belly leaving the normally weak portion of the transversalis fascia with little or no support. The rectus muscle is likely to be narrow and thin. As no preformed peritoneal pouch or protrusion exists at the point in the floor of the inguinal region where

direct hernia usually occurs, it is, strictly speaking, classed as of the acquired variety, however, the above described condition of the muscles in this region is unquestionably of congenital origin in many cases. The form of occupation of the patient does not seem to be responsible for the development of the hernia. It is conceivable that the condition will appear earlier in those doing hard labor than in those doing light work, but it is a fact that many of these hernias are seen in tailors,

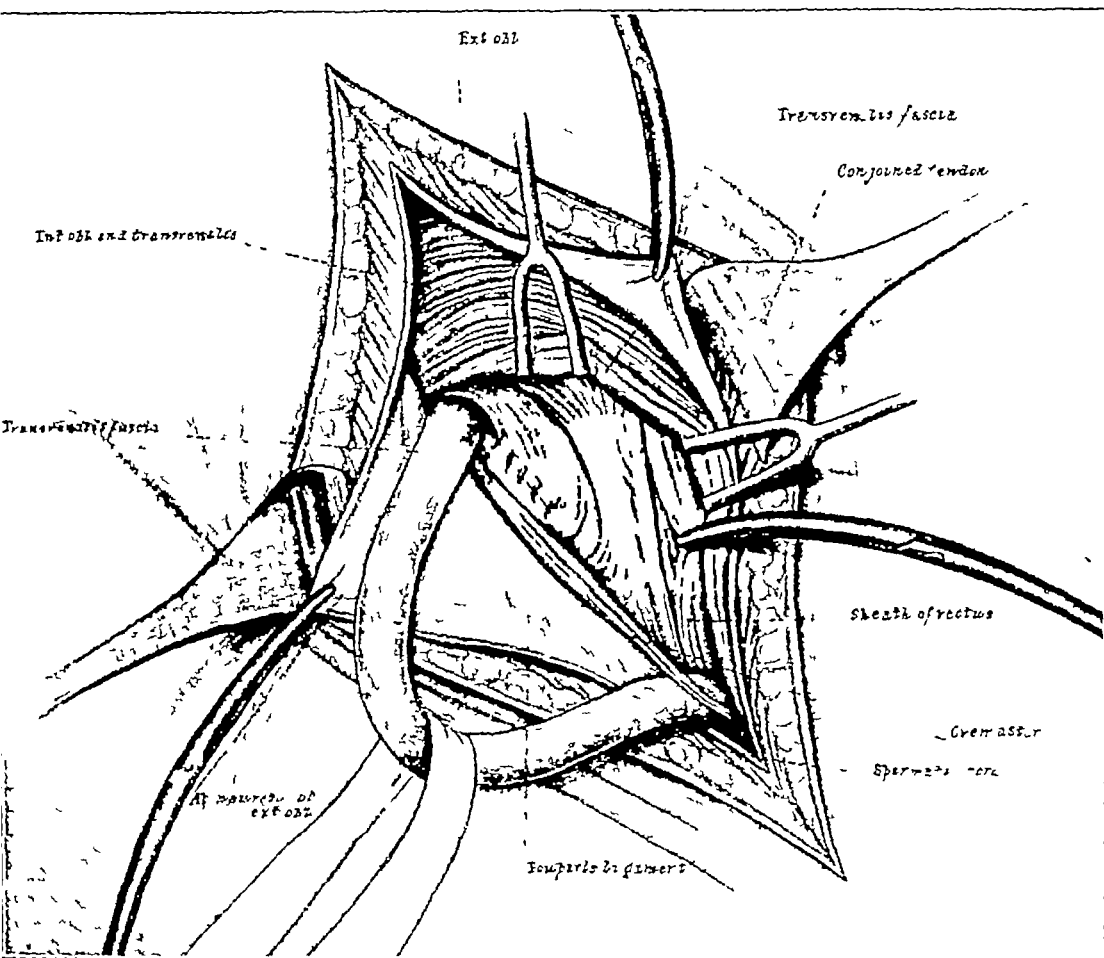


Fig 9—Closure of transversalis fascia as a separate layer, sheath of rectus opened

clerks and bookkeepers. The majority of direct hernias develop without giving rise to symptoms. Either the man notices a painless swelling in the inguinal region, or his attention is called to such a swelling while undergoing a physical examination for one reason or another. A certain number of patients will state that after an unusual effort at lifting or straining, they suffered severe pain in the groin and immediately noticed a swelling. Examination fails to reveal evidence

of an acute lesion, as would surely be the case if a trauma had been received of sufficient violence to cause a palpable mass. The extra effort has suddenly forced some portion of the abdominal contents into a sac, which has slowly formed without giving rise to symptoms. Some patients complain of dull pain or a sense of weakness in the inguinal region from the incipency of the hernia. Once the condition has developed to any extent, the symptoms are those usual to hernia in this region, with the exception that on account of the large size of the neck of the sac in the average case there is little tendency to strangulation.

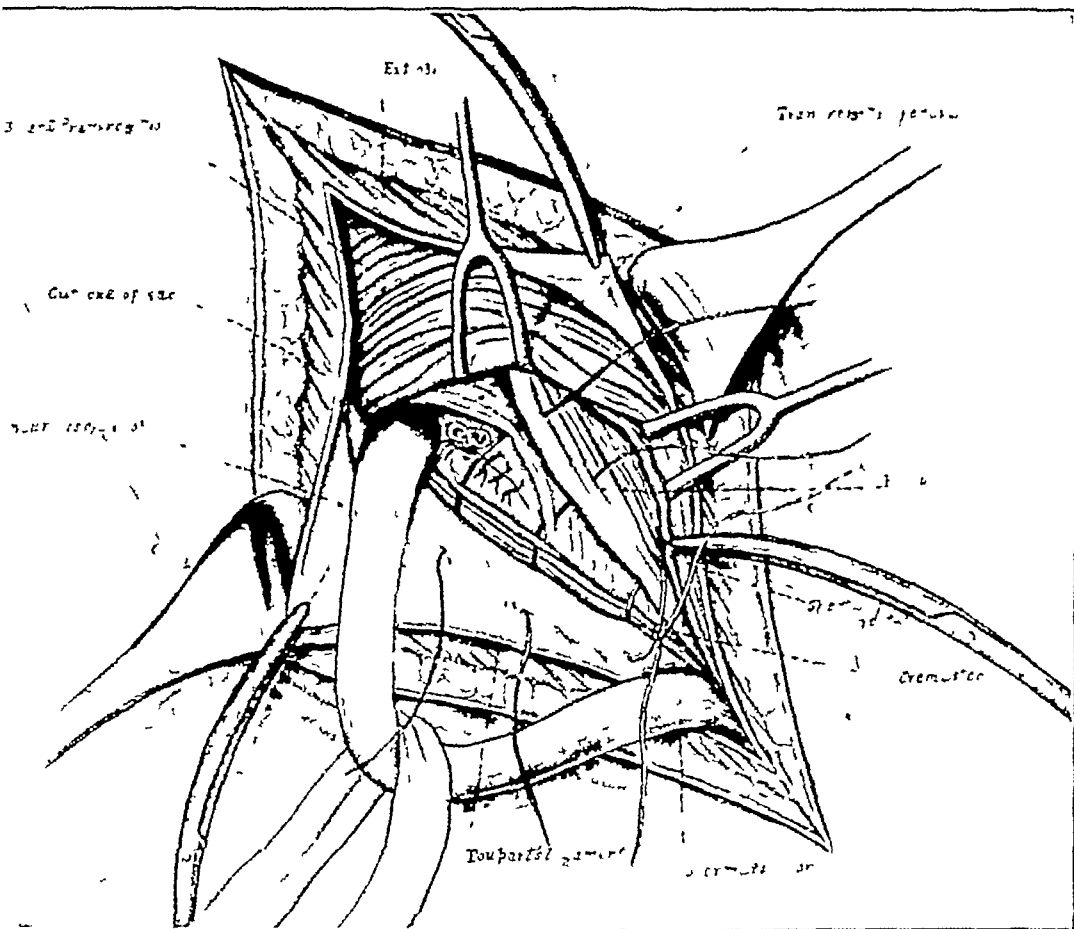


Fig 10—Rectus muscle exposed, sutures in place

If these points are borne in mind, the diagnosis of direct hernia is easily made in most instances. (1) Age and sex of the patient, (2) condition of the lower abdominal muscles, (3) the fact that the protrusion is often bilateral, (4) the situation which is low down over the pubic bone except in very early cases in which the sac has not descended to the external ring, (5) globular swelling which does not

tend to enter the scrotum even if of large size and is easily reducible, and (6) a definite weakness disclosed by palpation over the lower portion of the inguinal canal. By invaginating the scrotum through the external ring, the finger may be passed directly back over the pubic bone, and the margin of the rectus muscle easily palpated. Occasionally, the deep epigastric artery may be felt above. On the other hand, an exceptional case of indirect hernia will present a sufficient number of the physical signs just enumerated to make the differential diag-

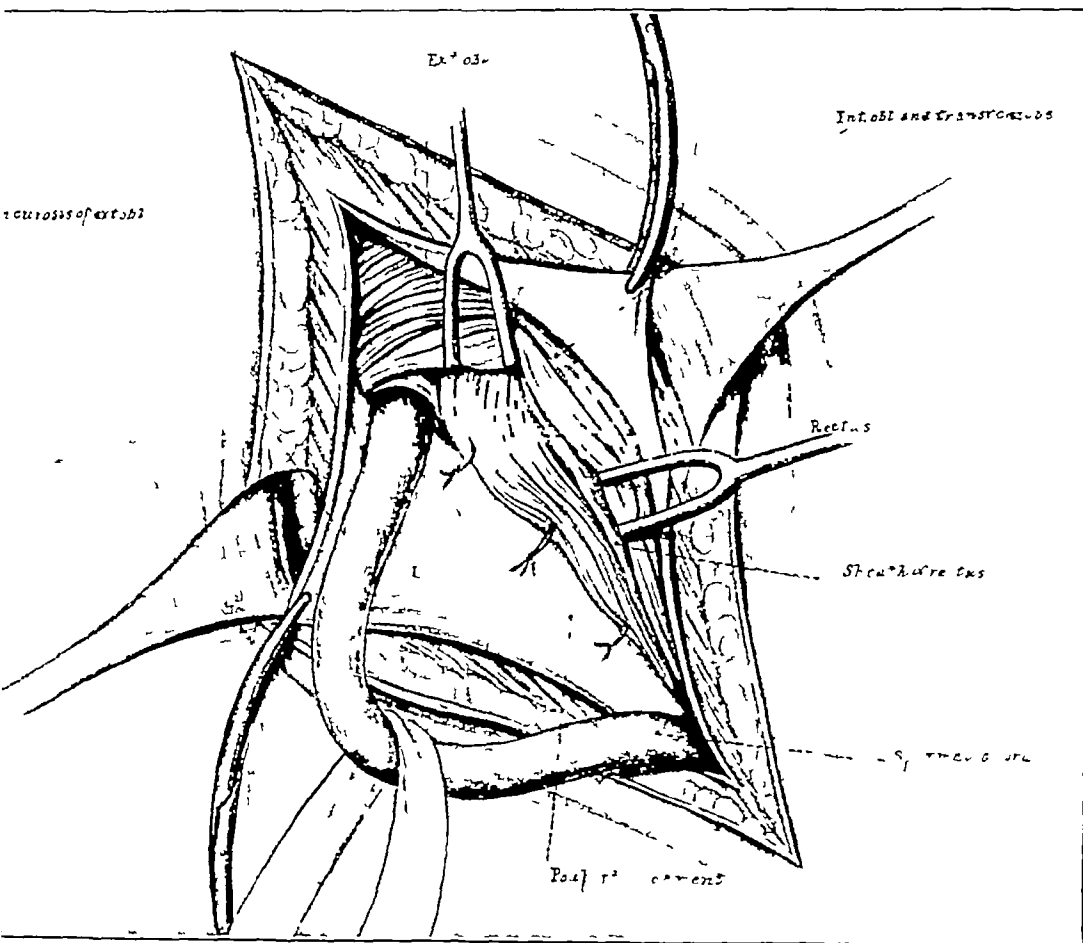


Fig 11—Rectus muscle in apposition to Poupart's ligament

nosis very difficult. It is practically impossible to differentiate direct hernia from hernia of the linea semilunaris. The latter occurs usually in persons with a considerable amount of fat in the pubic region, and for this reason palpation or exploration of the canal with the finger is not satisfactory. I know of no case of hernia of the linea semilunaris in this region that was diagnosed before operation.

TREATMENT OF DIRECT HERNIA

The results obtained in the operative treatment of direct hernia depend in a large measure on the proper selection of cases. Old men with weak muscles and relaxed tissues in general are poor subjects for the plastic type of operation necessary to cure this condition, and except for some very good reason they should not be operated on. The younger men with weak lower abdominal muscles, and an almost vertical pelvis should be examined with great care, and the effort made

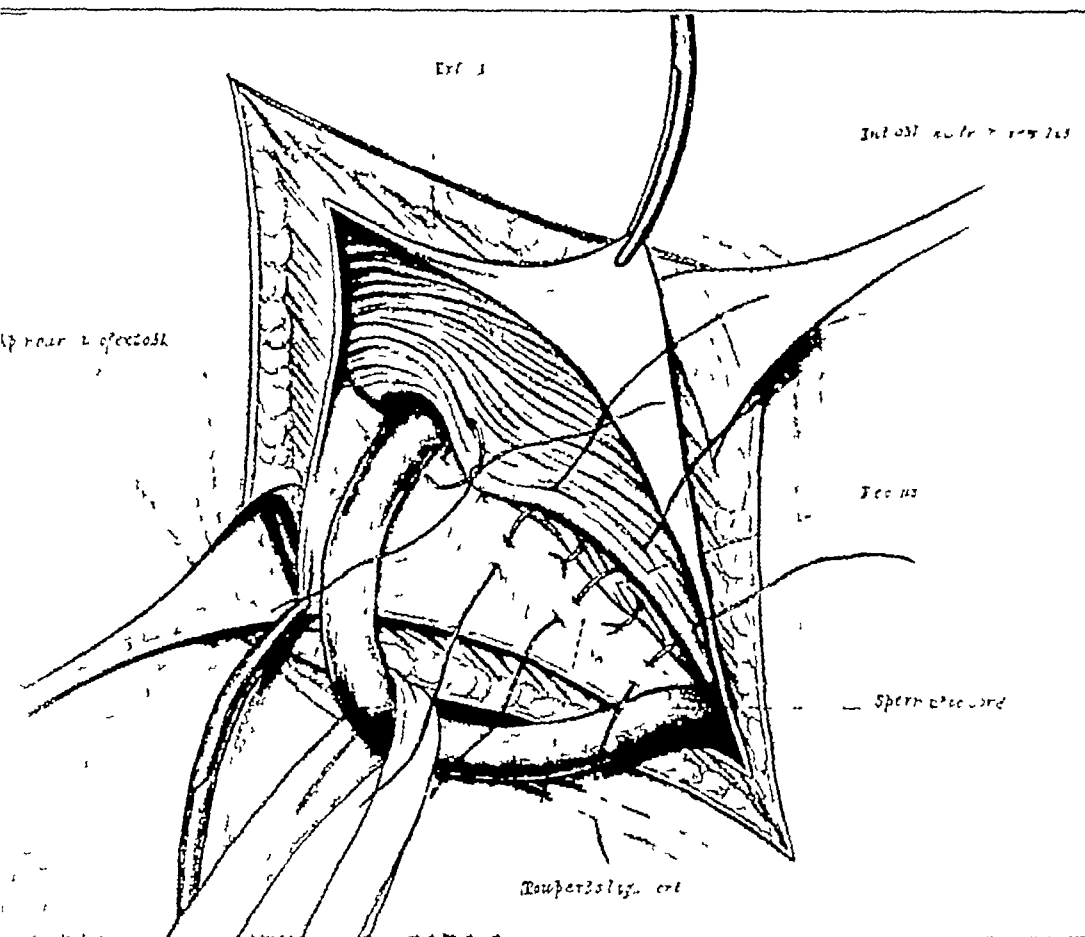


Fig 12—Bassini operation after rectus transplantation

to determine whether by any sort of operation the structures in the inguinal region can be so strengthened as to resist the intra-abdominal pressure which in these patients is apparently greater than the deficient musculature can withstand. The most unfavorable cases for operation are those in which there is a protrusion usually of small size occurring about the middle of the inguinal canal in which the external oblique is relaxed and very thin, or in which there is a separation of its fibers

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The external ring may not admit the tip of the finger, but with the patient lying down, one or more fingers may be passed through the hiatus in the external oblique muscle and the edge of the rectus muscle, or the pubic bone may be palpated. It is in this class of cases that I believe the patient's best interest will be served if a truss is applied just tight enough to balance the intra-abdominal pressure, and systematic exercise of the abdominal muscles advised. If the muscles are improved by the exercise and the hernia persists, the question of

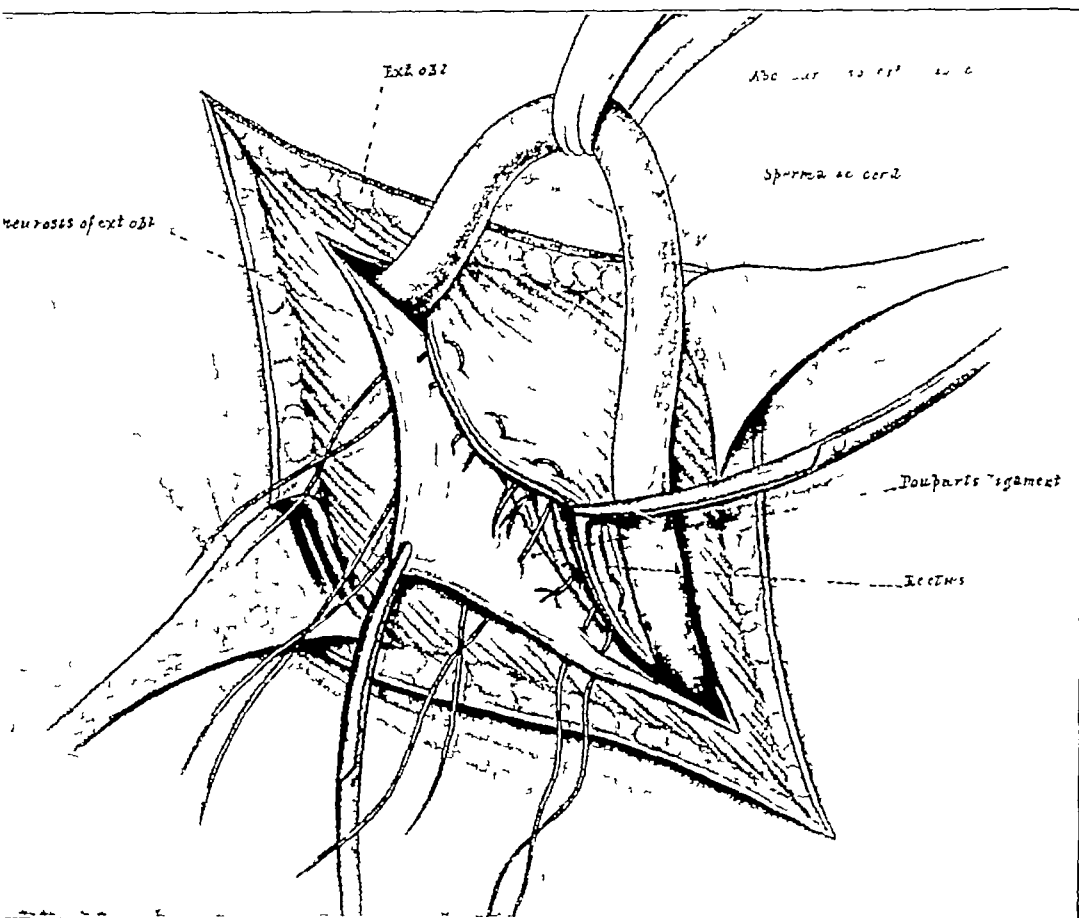


Fig 13—Andrews operation after rectus transplantation

operation may again be taken up in a period of from six months to a year. No patient with a chronic cough should be operated on unless there is danger of strangulation.

In the selection of the proper operation for a given case of direct hernia, just as much care should be exercised as in the selection of cases suitable for operation. While the great majority of these hernias fall into two general groups—the usual form in which the protrusion occurs through the normal weak portion of the transversalis fascia

and the combined direct and indirect type—yet an operation which will prove satisfactory in one case may be wholly inadequate in another. Anatomic variations explain this difference. In one instance, the muscles may be well developed, and any one of the well recognized operative procedures may give a perfect result. On the other hand, the muscles may be thinned out, poorly developed and the sac large, its base extending almost from the epigastric artery to the pubic bone. An entirely different operation is necessary if a satisfactory outcome is to be expected under such conditions. In spite of the fact that it is generally known that the structures differ in this way, many writers continue to group all direct hernias under one heading, and advise a given operative technic for all cases. Frequently, the operation recommended is one of the recognized methods used for the cure of oblique hernia. That this type of operation is inadequate in cases of direct hernia in which the muscles are undeveloped and the conjoint tendon absent or attenuated was recognized by Bloodgood¹ twenty years ago. This author, in an exhaustive report of cases in which operation was performed at the Johns Hopkins Hospital, showed conclusively that if satisfactory results were to be obtained in this form of rupture, something more than the routine technic must be employed. About 1909, I began the use of the transplanted or, more properly speaking, transposed rectus muscle in conjunction with the Bassini operation in the treatment of this class of cases. So many recurrences were taking place in my patients as well as in those of other surgeons with whom I was associated that it became quite evident that the Bassini operation alone did not meet the indications. Accordingly, I adopted the following method, which I have modified from time to time.

OPERATION

The usual skin incision is made, carrying the lower angle down to the pubic bone, as it is important to have a good exposure in the region of the external ring. The aponeurosis of the external oblique is divided well over toward the edge of the rectus muscle, and both flaps are retracted. The sharp margin of Poupart's ligament is then exposed down to the pubic spine. By blunt dissection, the fibers of the cremaster muscle are separated and the cord gently lifted from its bed. A small retractor is now placed under the arched fibers of the internal oblique and transversalis muscles, exposing the internal ring. By gentle traction on the cord, the peritoneal reflection at the internal ring is brought into view and the presence or absence of an oblique hernia quickly determined. This step is absolutely essential and should be carried out before attempting to isolate the direct hernial sac irrespective of its size or location, for in no other way can the error of overlooking the indirect portion of a combined sac be avoided. If no indirect sac is found, the direct is opened on its upper side in order to keep as far away from the bladder as possible. I believe that the sac should be opened in every hernia that is of sufficient size to warrant operation.

1 Bloodgood, J. C. Johns Hopkins Hospital Report, 1899

In the well developed cases, the transversalis fascia is thinned out, and as a rule there is little properitoneal fat. In the smaller ones the fascia may be quite firm and a large amount of fat present, causing considerable difficulty in locating the sac. The outer surface of the sac on its lower and inner sides is more or less covered by fat—usually spoken of as bladder fat—but which in reality differs in no wise from the properitoneal fat of other locations. With the finger inserted through the neck of the sac for support, the fat is gently stripped from its surface. As its lower limits is approached, a number of small blood vessels will be seen and a small tongue-like projection of bladder

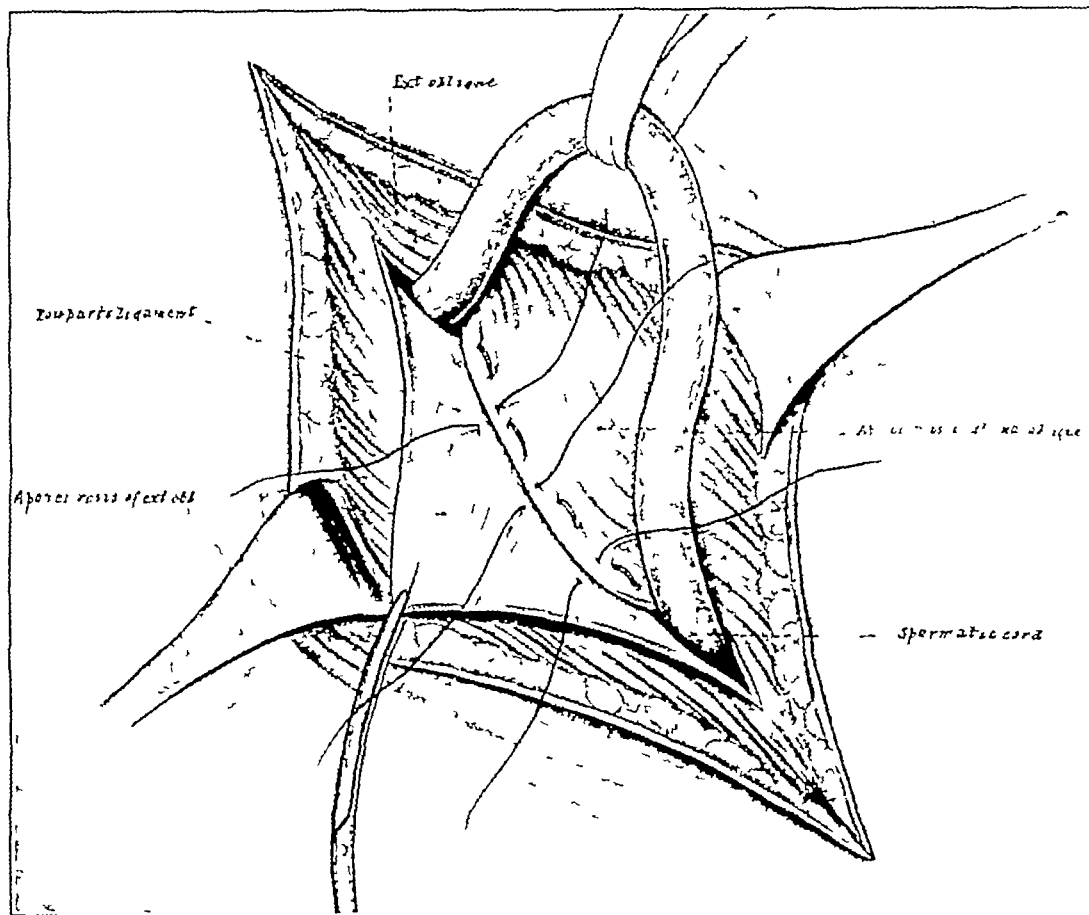


Fig 14—Suture of external oblique to Poupart's ligament. Continuous suture is preferred to interrupted, as illustrated.

muscle observed in most cases (Fig 7). These muscle fibers are rather pale in color and run somewhat parallel to the long axis of the sac. With ordinary care, the bladder should never be injured. The fat is stripped readily as a rule, but occasionally it may be found adherent from the long continued use of a truss. Frequently the obliterated hypogastric artery, a dense fibrous band, will be encountered as the stripping proceeds toward the bladder. This structure, often referred to as indicating the lowest limit to which the fat may safely be removed, is of no value whatsoever as a guide to the bladder. Its location varies in nearly every case. At times it is taut, dividing the fatty mass into

or below it at will. It should be cut if it interferes with proper dissection. After the sac wall has been satisfactorily exposed, its base should be drawn flush with the opening in the fascia and transfixed, or, better still, if of large size, sutured as in the manner of closing the peritoneum in laparotomy wounds (Fig 8). I always use No 1 chromicized catgut for this purpose.

In the cases of combined direct and indirect hernia, the two portions of the sac should be converted into one, by drawing one or the other above or below the deep epigastric artery, being guided by their relative size as to whether it is best to convert the direct into an indirect or vice versa (Figs 4 and 5). I formerly advised dividing the artery in this type of hernia (Fig 6), but I am

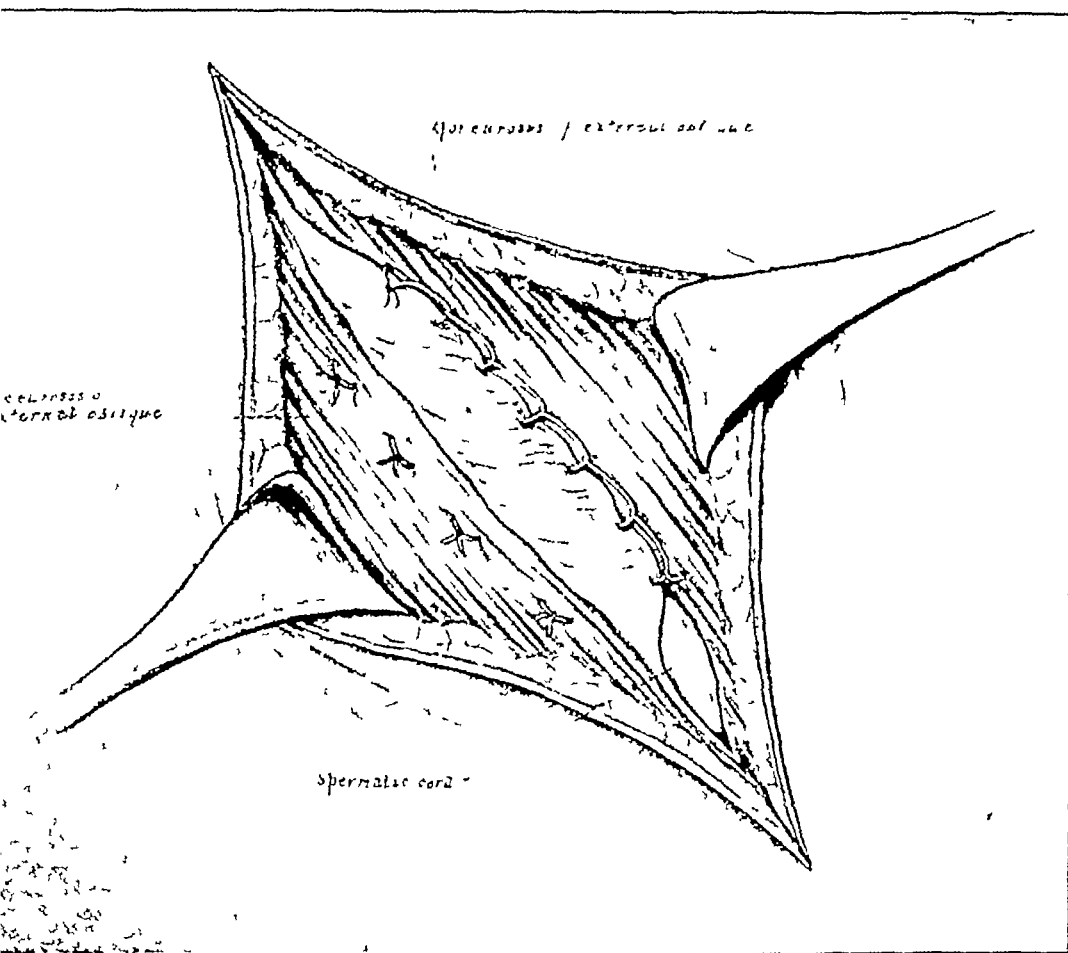


Fig 15—Andrews operation completed

now of the opinion that the sac can be removed in most instances just as thoroughly without sacrificing this vessel. These hernias should all be classed as direct and handled as such. After the sac has been disposed of, the rent in the transversalis fascia should be closed if possible, a continuous suture of chromic gut being utilized for the purpose (Fig 9). A second retractor is now placed low down under the continuation of the internal oblique and transversalis muscles, and the sharp margin of the rectus muscle located with the finger. The sheath of the rectus is then opened along its anterior border, and the muscle exposed from about the level of the internal ring down to its pubic

attachment (Fig 9) Three to four sutures of kangaroo tendon are introduced between the outer portion of the rectus muscle and the deepest part of Poupart's ligament. If the transversalis fascia has not been closed satisfactorily as a separate layer, it should be included with these structures. The sutures should be placed from one half to three quarters inch apart and inserted from below up—the lowest one passing from just above the insertion of the rectus muscle to the terminal portion of the ligament (Fig 10). After they have been properly placed, gentle traction should be made on the sutures drawing muscle and ligament well together, and while thus held by an assistant, they should be tied in the order of their insertion (Fig 11). The usual Bassini operation

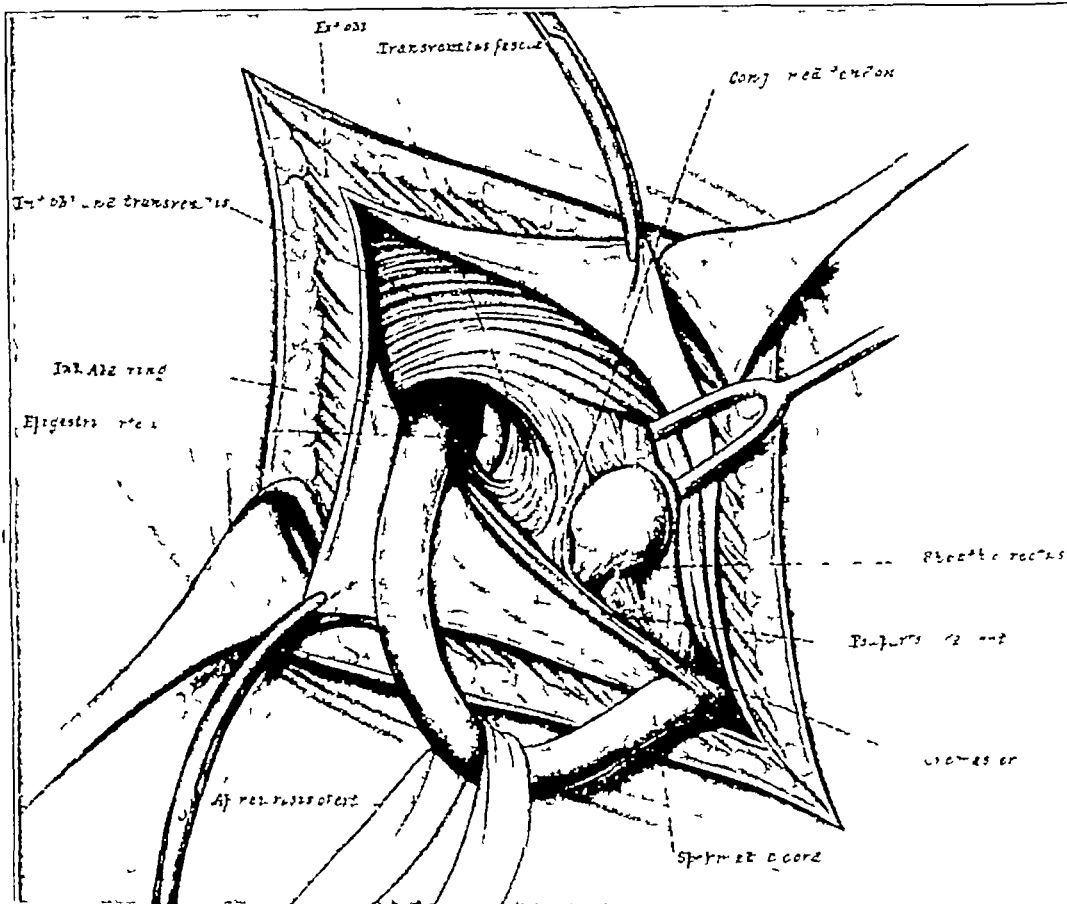


Fig 16—Hernia of linea semilunaris

is now performed from above downward, the sutures picking up a small bite of the rectus muscle and catching Poupart's ligament just superficial to and between those of the first row (Fig 12). Excessive fat should be removed from the cord, but the veins should not be excised. In closing the external oblique, care should be taken to restore the external ring to as near normal as possible. The hernia of the linea semilunaris in this region is closed by removal of the sac, and the use of one or two mattress sutures placed between the margin of the rectus sheath and the conjoined tendon and transversalis fascia followed by the Bassini or Andrews operation. As these hernias are in close proximity to the bladder, the sac should be dissected with great care.

COMMENT

Complete removal of the sac is the most important step in the operative treatment of any form of hernia, but it is necessary to provide sufficient support at the weakened area in the abdominal wall in order to prevent recurrence. In indirect inguinal hernia, proper use of the internal oblique and transversalis muscles satisfactorily overcomes this weakness, but in the direct type, these muscles alone do not meet the requirements. By making use of the rectus muscle, an additional layer is added to the weakened posterior wall of the canal. It is not asserted that the fibers of this muscle form a true union with Poupart's ligament or that they always remain permanently in the new position, but they do aid greatly in the formation of new connective tissue at a point where every bit of additional support is of value in the prevention of recurrence. By the use of the foregoing method recurrences in my cases have been reduced more than half, and now that I am selecting the cases for operation with greater care, I believe that the permanent cures will show a still further increase.

Eucouraging, however, as these results may be in some ways, I feel that there is still room for improvement in the operative treatment of direct hernia. With this object in view, my assistant, Dr R W Bolling, and I have recently decided to combine transplantation of the rectus muscle with the Andrews operation instead of the Bassini in the hope that this combination will give even better results (Fig 13). The mattress sutures are placed as recommended by Andrews for his posterior operation with the addition of a continuous suture between the margin of the external oblique flap and Poupart's ligament (Fig 14). This stitch of fine gut insures closer contact between these aponeurotic structures. The lower flap of the external oblique muscle is then sutured over the cord in the usual way (Fig 15). If there seems to be tension in the upper flap of the external oblique muscle, a free liberating incision may be made through the sheath of the rectus well back over the belly of the muscle and parallel with its fibers. It might be said in passing that sutures placed under tension are of little or no value as they soon cut out. Kangaroo tendon or chromic catgut was used for all deep sutures up to the time of changing methods, but we are now trying celluloid linen in one series and absorbable sutures in another.

COMPLICATIONS

Two accidents occurred in this series of cases—both about ten years ago. One was in a recurrent hernia in which the vas was cut as the incision was made through the skin. The cord had been placed superficial to the external oblique aponeurosis at the original operation. In the other, a large hernia with much properitoneal fat, the

bladder was opened, but the injury was recognized and no ill effect followed. This is the only time I have ever seen the bladder opened during an operation for hernia, nor have I ever seen the iliac artery or vein injured in this operation. Hematoma of the cord seldom follows operations for direct hernia, owing to the fact that the sac is rarely adherent to this structure. Postoperative hydrocele is of such rare occurrence after operation for this form of hernia that I would almost be inclined to look on this condition as a coincidence rather than a result. As a matter of fact, the various forms of tumefaction in the scrotum referred to by Seward Erdman² as occurring after the hernia operation are rarely seen, provided the cord is managed correctly during the operation, and the scrotum properly supported by a well fitting suspensory afterward. In no instance has atrophy of the testicle been noted in following up these cases. The patient in which the vas was divided was lost track of shortly after operation.

Since 1909, I have operated by the method referred to, that is, rectus transplantation combined with the Bassini operation, on 249 patients with direct hernia. In sixty-nine, the hernia was bilateral, making a total of 318 operations. Ninety patients have been followed for one year or longer, including twenty-three in whom the hernia was double. In this total of 113 operations, there have been six recurrences, or a recurrence of somewhat less than 5.5 per cent. It is suggestive that three of the recurrences followed operation for bilateral hernia performed at one operation.

CONCLUSIONS

- 1 The patient with a direct inguinal hernia should be carefully studied before recommending operation. If the condition of the lower abdominal muscles is such that a fair chance of obtaining a cure cannot be offered, the question of operation should be deferred for the time being and the patient advised to take systematic exercises for a period of from six months to one year.

- 2 There is a small but definite group of patients with poorly developed muscles on whom it is not wise to operate for this condition, as recurrence is almost certain to follow.

- 3 Complete removal of the sac and the use of the rectus muscle in conjunction with one of the recognized operations for indirect inguinal hernia have reduced our percentage of failures in direct hernia more than half.

² Erdman Seward. *Ann Surg* 66 702 (Dec) 1917

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² Erdman Seward. *Ann Surg* 66:702 (Dec) 1917.

A REVIEW OF EIGHT YEARS' EXPERIENCE WITH BRAIN TUMORS *

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In previous papers, I have considered various phases of neurologic surgery. In this paper I shall discuss my series of brain tumors, which number eighty-five. These unquestionably present the most difficult and varied problems which the neurologic surgeon encounters.

In a recent paper read before the Clinical Congress of Surgeons, Cushing said that the time had passed when there is any purpose in speaking of the mortality in brain tumor cases any more than there is in speaking of the mortality in abdominal tumor cases. That such a generalization leads nowhere is also apparent in a study of my cases, and would be most discouraging were we to content ourselves with the bald statement that of the eighty-five patients, we lost twenty-nine, or 35.5 per cent. But when we study these cases from other angles, we find that eighteen of these twenty-nine deaths were in patients suffering with glioma, and that sixty-four, or a little more than 74 per cent, of the patients had tumors other than glioma, and the mortality in these cases was only 17 per cent. There would be other ways of studying these figures, and I doubt not that it might be possible to juggle figures so that I could claim an even lower mortality for certain groups of cases. That, however, is not my purpose. The outstanding fact is that the largest mortality in brain tumor cases occurs in those patients that have gliomas. Let us, therefore, first consider the problem of gliomas.

TYPES OF GLIOMAS

What are the facts about gliomas? Some grow by replacing tissue and others by displacing tissue. Those that do not add to the cranial contents and merely replace tissue do not give rise to any general symptoms of increased pressure, and the only symptoms we observe are focal phenomena, irritative or paralytic in character. The focal symptoms may be the prominent or only features of a case, and though

* Read before the Academy of Medicine, Kansas City, Mo., March 12, 1920

the tumor may grow to be quite large, it may give no general signs whatever of pressure. This cannot be emphasized too frequently. A diagnosis of brain tumor may be made though there are no general signs of pressure. Because this fact is not recognized, early interference is often not undertaken, but early operation is more important.



Fig 1—Patient with tumor which was removed four years ago. With the glioma there was a large cyst at least twice as large as the tumor. The only observable symptom the patient now has is a defect in past pointing in one hand.



Fig 2—Patient with glioma which showed no cystic degeneration.

in dealing with this type of tumor than with any other. Gliomas are frequently spoken of as malignant tumors, but this is, in my opinion, not correct, for one of the chief characteristics of a malignant tumor is the fact that it metastasizes, and this gliomas never do. Infiltration of surrounding tissue can hardly be the criterion of malignancy in judging gliomas on account of the peculiar structure of brain tissue.

itself Infiltration may be used as a criterion of malignancy when the tissue involved has sharp lines of demarcation itself, but the glia reticulum, which is the foundation structure of brain tissue, is itself diffuse and without these lines of demarcation so that infiltration cannot be properly assumed as a test of malignancy in gliomas If we go beyond the limits of a glioma, we can remove it radically I have a few cases in my series which bear this out (Figs 1 and 2)

We have preached and pleaded for years that brain tumor cases must come to operation early, and various periods have been set during which other treatment could be tried My study of these cases brings out some interesting facts on this very point The only successful

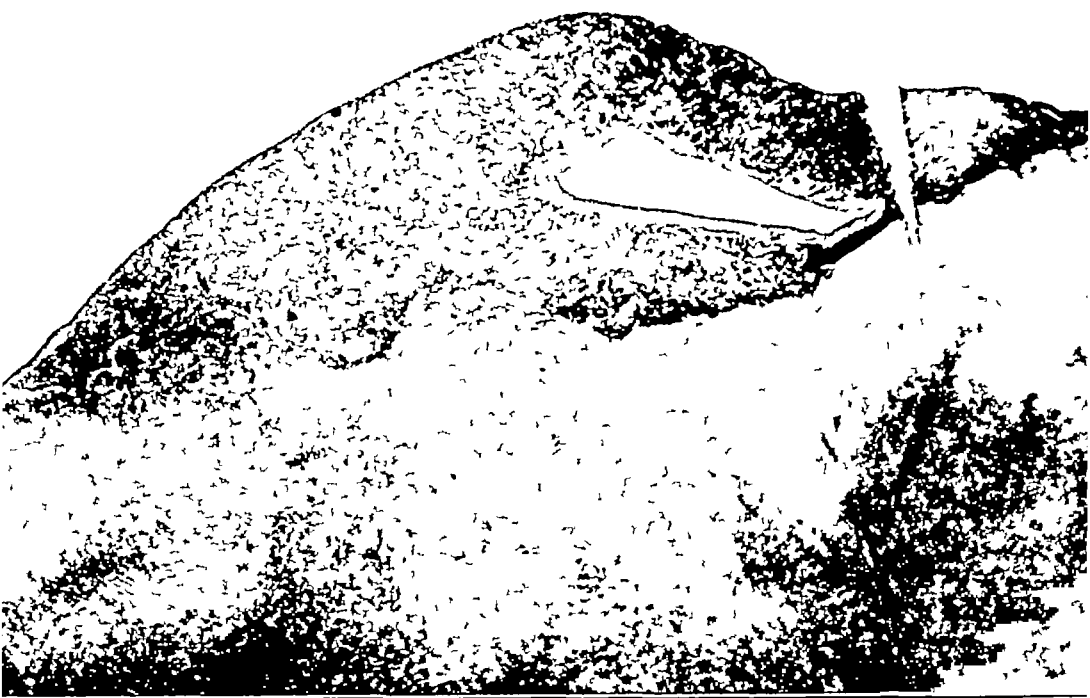


Fig 3—Glioma in which a large vein that ran directly through it had to be ligated A very marked cerebral edema developed which should have been provided for by a decompression Eight years ago, when this operation was performed, the importance of adding a decompression operation was not appreciated This is the type of glioma in which only glia nuclei predominate

extirpations of gliomas we have had were in patients whose symptoms were present four months or less, though there were several that I lost that I think I could save today that had had the symptoms for a little longer time Therefore, four weeks should be the longest time to try palliative measures, and using dilatory methods that extend over months is absolutely wrong and unjustifiable Every brain tumor should be treated on the theory that it may be a glioma, and should

be grouped with the most urgent cases that need hospital treatment. Of the gliomas in this series, 26 per cent were readily removable, though our successful extirpations constituted only 14 per cent. One patient would have been saved had a donor for transfusion been in readiness, a contingency for which we always provide now when we expect an extensive tumor removal. The other would have been saved had a decompression been combined with the tumor removal to take care of the inevitable edema that takes place in all such cases (Fig 3)

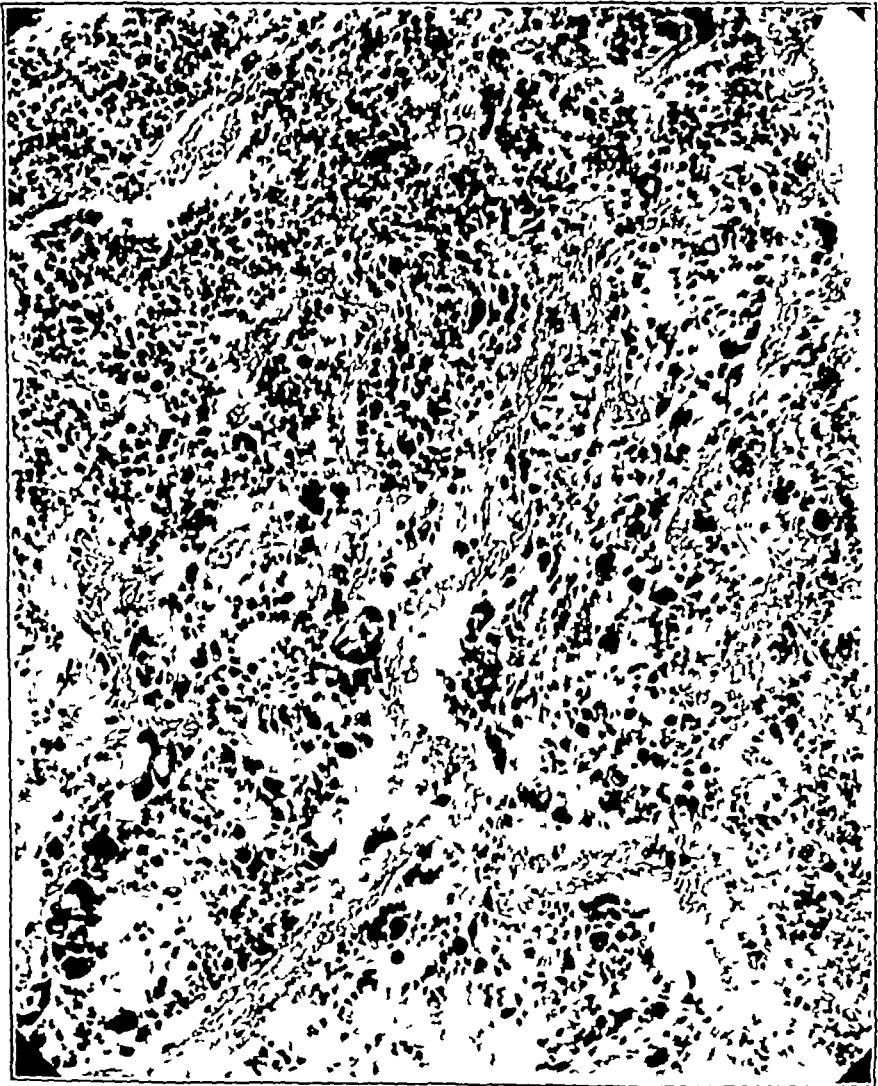


Fig 4—Glioma containing various types of cells. Many giant cells present.

Another phase of the question is whether the gross pathology of a glioma gives one any clue as to the type of glioma one is dealing with, and to what extent the character of the glioma influences the prognosis. I have found most useful the classification of gliomas that was employed some years ago by Tooth in his analysis of the cases at the

London Queen's Square Hospital for paralyzed and epileptics. According to this classification, there are three types. First, that in which the glia nuclei predominate. These cases have often been called sarcomas, as the underlying network of glia reticulum has been overlooked (Fig 3). Second, that in which there are glia cells of varying size. Some of them are giant cells with multiple nuclei and are not unlike

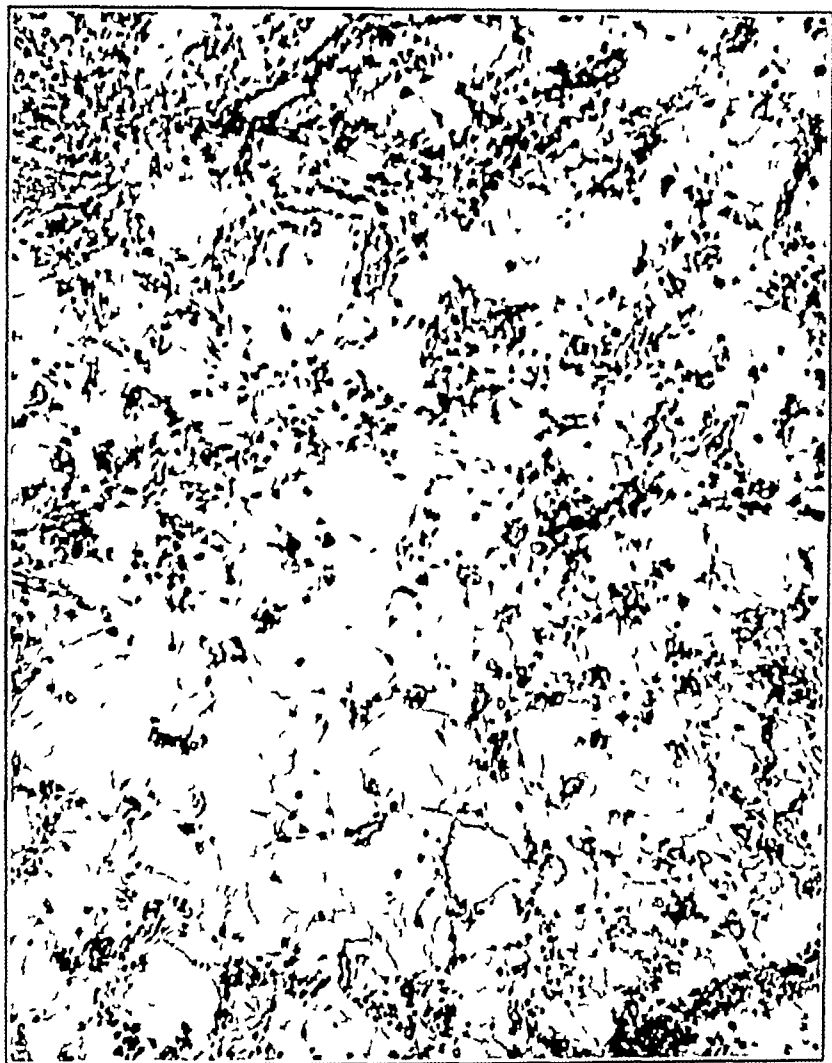


Fig 5—Glioma containing few cells and much reticulum

the giant cells in a giant cell sarcoma (Fig 4). Third, that in which there are few cells and which is made up mostly of a very loose reticulum (Fig 5). I doubt whether any one can recognize the type of glioma from the gross appearance, though with a larger experience that may be possible. I have the impression, however, that the last group I mentioned is the most unfavorable, and is the most rapidly growing glioma.

DEFORMITIES AND MORTALITY IN THIS TYPE OF TUMOR

A question that naturally suggests itself is whether the type of operation is responsible for the mortality. This seems to play no rôle, for practically as many patients died after a simple decompression as after an extensive bilateral cerebellar exposure or osteoplastic flap over the cerebral cortex. What, then, are the factors responsible for the deaths and how can they be obviated?

Do gliomas produce conditions in the cranial cavity that other tumors do not produce at all, or not so markedly? In studying the specimens of fatal cases, I have been impressed with the fact that the brains in cases of gliomas are much more deformed than in other types of tumors (Figs 6 and 7)



Fig 6—A glioma which markedly deformed the pons

Gliomas differ from other tumors in three respects (1) They are faster growing, (2) they are very soft in consistency, and (3) they are not encapsulated

Are all or any of these factors responsible for these deformities? A rapidly growing tumor may produce more deformity of a brain than a slowly growing one because the brain is not able to accommodate itself and instead of becoming compressed locally, thus making room for the tumor, it is pushed away *en masse*. Slowly growing encapsulated tumors make room for themselves by causing a local atrophy. That rapidly increasing pressure may produce such deformity

is well illustrated in a traumatic case (Fig 8) A tumor of soft consistency might also bring this about Other possible explanations that have been suggested are that the tumor, since it is soft, would far more easily take up fluid from the adjacent brain substance by osmotic action, dehydrate it, and make the normal brain smaller in volume Then, too, in rapidly growing tumors the blood vessels do not have the well developed elastic layer that normal vessels have and consequently can be more easily compressed, and secondary edema would occur much more readily Neither of these, however, seems an adequate explanation The latter fact explains, I believe, why gliomas readily become edematous and take up more room after pressure has been released by a decompression operation, but it does not account for cerebral deformity I have thought that possibly gliomas not being encapsulated, may create different pressure conditions in the

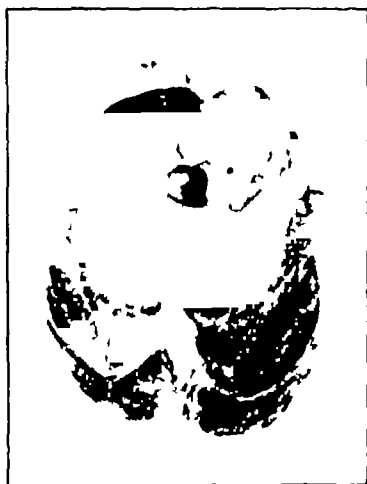


Fig 7—A gumma of about the same size and in about the same region as that in Figure 6 which has caused no deformity at all

cranium than processes that are well encapsulated Physicists I have consulted have been unable to give me any explanation that would support such an idea I am, therefore, inclined to explain the deformity that we know occurs by the first of these three factors—the rapid growth

A very important part of the treatment of gliomas consists in dealing with these deformities If a tumor is removed in a case in which such a deformity exists, the sudden release of pressure results in the compressed and deformed brain trying to fill up the space, and the great edema that results may throw out of function centers at some distance from the tumor and thus cause the patient's death Therefore, before removing a tumor we must try to reduce this deformity which can best be done by a decompression operation on the side of

the tumor, for if the decompression should be performed on the side opposite the tumor, the deformity would be increased. This is one of the principal reasons for performing operations in tumor cases in several stages. Thus, in these eighty-five cases we have performed 106 operations. To work in the intracranial cavity while the pressure is markedly increased is an unwise and well nigh impossible procedure. A preliminary decompression helps to reduce the pressure, but in addition to this, the dura if possible should never be opened until the intracranial pressure has been reduced to normal or slightly below normal. This is done most safely by withdrawing the fluid from the

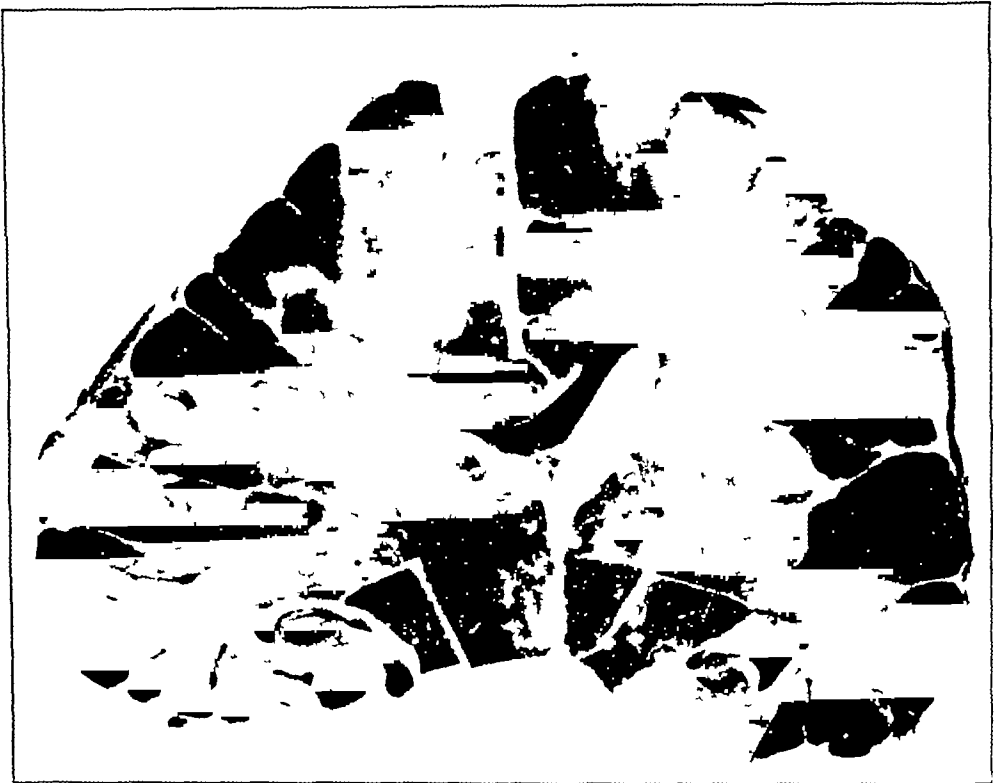


Fig 8—Specimen from patient with hemorrhagic leptomeningitis. The compression of the brain was produced by the large collection of fluid, and the sudden release of this fluid caused edema of one cerebral hemisphere.

ventricle, not by lumbar puncture. Even after a bone flap has been turned down, lumbar puncture may result in a dropping down of the cerebellum on the medulla, resulting in the inevitable medullary collapse. Not infrequently the ventricle on the side of the tumor is collapsed, so that I make it a rule to take the fluid from the opposite ventricle. I have no other rule as to the amount of fluid I remove than to reduce the pressure as evidenced by the tenseness of the dura to normal or slightly below normal. I realize that this method is

crude, but until some one makes a tonometer similar to the one used by ophthalmologists to test intra-ocular tension, we must be content with this method. I have performed about 100 ventricle punctures, and have never yet observed any harm resulting from the procedure.

In the removal of a tumor, the surrounding brain tissue should be handled very gently, and the finger should if possible never be used for this purpose. Blunt dissection, I think, is preferable to a knife.

PROCESSES OTHER THAN TRUE BRAIN TUMORS

The other cases in this series include a considerable variety of processes, and the question might well be raised whether it is proper to call them all true tumors. The reason for this is that the pre-operative diagnosis in these cases was brain tumor, and that at operation increased pressure was found in those cases in which the tumor was not looked for or not found, or a lesion which acted like a tumor was found, though it might not have been a true neoplasm, for example, a cyst.

This group contained sixty-four cases with eleven deaths, a mortality of 17 per cent. Twelve of these cases were cysts. They were of various kinds. In one or two of them probably there was a glioma underlying the process, but the operation did not reveal the tumor, and unfortunately in neither of these two cases—one patient died two months after operation—were we able to obtain a necropsy. The fluid in both of these cases was brownish, but as it was not gelatinous we could not be positive that we were dealing with a glomatous cyst. The third patient in this group that died had a huge cyst which had completely replaced the vermis. The patient developed a cerebro-spinal fistula about the sixteenth day after operation, and this, I think, must have permitted an infection to get in which led to her death twenty days after the operation. There was no necropsy obtained in this case, but unquestionably the condition was not associated with a glioma, for the cyst contained clear fluid. At that time (1913) I did not understand the pathology of this cyst, but some recent work of Beneke contains the explanation for this and some other cases that I have observed from time to time.

In thinking about and seeing cases of birth hemorrhage, I had believed the majority of them occurred over the cerebral cortex, but Beneke points out from a study of the stillborn that by far the larger number of birth hemorrhages occur in the posterior fossa and are due to rupture of the fibers of the tentorium of the cerebellum. Most of the patients with tentorial hemorrhage die, but undoubtedly some survive, and such a cyst as I found in this case might well have been produced in this way. I should like to point out in passing that some of the patients with spastic paraplegia due to birth injury in which

there are marked ataxic movements and little spasticity may well have had a posterior fossa hemorrhage and either a cyst or adhesions about the foramen magnum producing an obstructive hydrocephalus

The other cysts were either traumatic in origin, or in one or two instances they were huge porencephalic cavities, a condition which, so far as I know, has never been definitely explained by the pathologist. The usual view is that it is a congenital defect

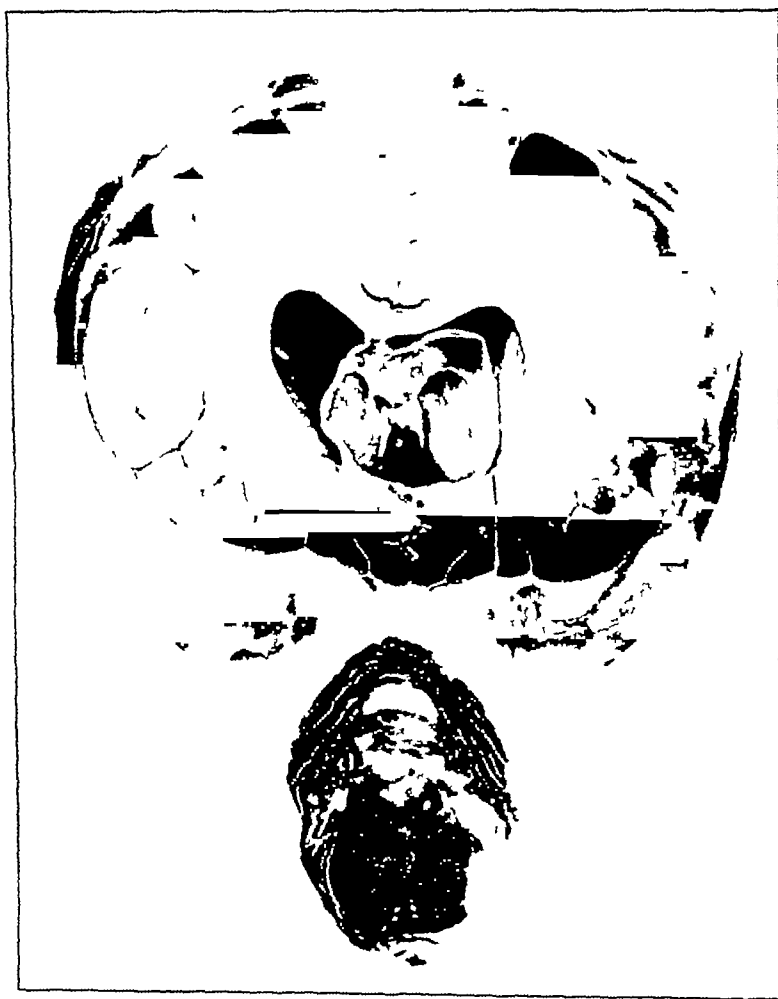


Fig 9—Multiple cysts of *Taenia solium* causing symptoms of brain tumor

The next large group in this series is composed of thirty cases which we have diagnosed as brain tumors, indeterminate, that is, the patients had symptoms of brain tumor, but decompression operations were performed only to relieve the general pressure symptoms because no focal signs were made out, or explorations were made which did not reveal the pathologic process. Some of these cases will in course of time, be reclassified and put into other groups when we learn their pathology. In this group there may be cases of so-called pseudo-

tumors, but such a diagnosis should not be made until necropsy has shown the absence of any other pathologic lesion

An analysis of this group could well be made the subject of a separate study, for the problems it presents in the way of diagnosis are very numerous. One such case that ultimately was taken out of this group may serve as an interesting example. The patient, a butcher, first presented cerebellar symptoms. A cerebellar exploration revealed great pressure but no tumor. He was relieved and went back to work. Some months later, he returned with a new set of symptoms which pointed to the pituitary, and a sella decompression was performed. This relieved him to some extent. Three months later, he suddenly died and necropsy disclosed the cause of death to be a small pontile hemorrhage, but the necropsy in addition revealed multiple cysts of *Taenia solium* (Fig 9).

This group illustrates very strikingly the fact that palliative procedures often afford a surprising amount of relief and for a considerable time. To prevent a patient's becoming blind and to relieve the headaches are in themselves well worth while, though it may only mean that the patients have relief for a few months or for a year or two.

The other cases in this group comprised a few each of various types, not enough of any one variety to justify any conclusion or deductions in this paper, in which I have attempted to treat of groups rather than individual cases.

RELATIVE PROGNOSIS OF THE TWO GROUPS

In considering collectively the sixty-four cases comprising the second portion of this paper, it is striking to note how very much more favorable these cases were than the first group, and also that many of these patients had had the symptoms for a long time, several years, and nevertheless were relieved. The word "relieved" is used advisedly, for to speak of a cure in the case of a patient suffering from a tumor is always questionable. The length of time that has elapsed since operation and the amount of disability that is present are points that have to be considered in arriving at a proper appraisement of the patient's status when discharged.

We must admit frankly, also, that it is infrequent to have a patient so completely relieved of the symptoms that no trace of the malady remains. This is due to the fact that the cerebral lesion has destroyed or impaired some function, just as disease elsewhere in the body also does, but the impairment after a cerebral lesion may be much more apparent. Occasionally, however, we succeed in restoring a patient so perfectly that only the most careful scrutiny reveals any defect. Such, of course, must be the goal toward which we continue to strive.

AMPUTATION NEUROMAS

THEIR DEVELOPMENT AND PREVENTION

G CARL HUBER, M D, AND DEAN LEWIS, M D
ANN ARBOR, MICH CHICAGO

Odier at the beginning of the nineteenth century first described the enlargements or swellings which develop on the distal end of a proximal segment of a peripheral nerve after partial or complete division. He spoke of these as nerve tumors. Since that time these enlargements, or neuromas, have been frequently studied. Interest in them has often been stimulated by war, for the number of painful stumps following amputations necessitated by mutilating wounds or infections have made a study of neuromas, with a view of determining the factors concerned in neuroma formation and the cause of spontaneous pain after they have developed, imperative.

The histologic descriptions of neuromas differ widely. The variations are easily explained, for when the earlier histologic examinations were made, histologic methods were not refined and specific stains were not employed. With the introduction of the silver method, which permits of clear differentiation of the neuraxes, the descriptions have become more uniform. It is possible to determine now what rôle the different tissues entering into the formation of the nerve play in the development of the neuroma.

Scar tissue has been considered by many as the determining factor in neuroma formation. Senn, in an article published in the *Yale Medical Journal* in 1897, states that it is well known that amputation neuromas will only develop in connection with scar tissue and the irritation incident to the condition producing it, and that every neuroma will be embedded in more or less scar tissue. It is more than probable that the cut ends of the nerve fibers become attached to the scar tissue which acts the part of a foreign substance and excites the active and abnormal proliferation on which depends the formation of the neuroma. Senn quotes thus from an article published by an assistant of Nicoladoni in substantiation of his views:

The numerical increase in nerve fibers is apparent and not real, for the increase is due to the formation of loops growing out of the elongation of preexisting fibers. With proliferation or growth of these fibers the interstitial connective tissue proliferates under the same influence the resulting tissue constituting histologically a true neurofibroma.

The importance of scar tissue as a factor in the causation of neuromas has been as already stated emphasized by many. The true amputation neuroma forms only on the distal end of the proximal

segment of a divided nerve. The occurrence of these bulbous enlargements only on the distal end of the proximal segment of a divided peripheral nerve and the fact that they are peculiar to nerves suggests that there are certain changes occurring during nerve repair which, when it does not pursue its regular course, ends in the formation of these bulbous enlargements. It will be shown by experiments which will be discussed later that neuromas develop on nerves in the absence of scar tissue or when it is reduced to a minimum and in wounds in which healing by first intention has occurred.

HISTOLOGY OF NEUROMAS

It will not be necessary to review at length the different opinions which have been expressed concerning the histology of neuromas and their significance. It will be interesting to note, however, a few of these.

Langstaff found in neuromas no evidence of the normal structure of a nerve. Probst and Smith regarded the neuroma as composed of fibrous tissue without any nerve elements, while Legoust and Guérin thought the simple neuroma to be caused by a hypertrophy of the connective tissue elements of the nerve.

Chauvel made microscopic examinations of thirty-two neuromas. He found nerve fibers in these. The fibers increased in number from the periphery to the central part of the bulbous enlargement. He also found nerve fibers passing beyond the enlargement to end in the connective tissue lying beyond the cut end of the nerve. He believes that the neuroma is caused by the growth of the endoneurium and perineurium, and that although nerve fibers are found passing through the enlargement, they do not undergo any change. Virchow in 1858 described the neuroma as consisting of a thick network of axis cylinders between which were scattered small amounts of connective tissue. He found the nerve fibers arranged in bundles or funiculi of varying but considerable size. These were surrounded by perineurium which separated them sharply from one another.

Kolliker believed that the neuromas which develop in clean wounds and in wounds in which there are no foreign bodies are new growths which are composed almost entirely of nerve tissue. Another group which develop in infected amputation wounds he regarded as inflammatory in character and as an expression of regenerative energy. More or less newly formed fibers are always found in these enlargements.

Gottsacker thought that the neuroma developed as the result of hyperplasia of the elements entering into the formation of the nerve. The enlargement forms not as the result of the rolling up of nerve fibers, but as the direct result of increase in numbers. Some of the

neurofibrillae grow beyond the cut surface of the nerve and form a tangle of nerve filaments in the connective tissue beyond it. The non-medullated fibers in the neuroma are but early stages of the medullated.

Klebs regarded the neuroma as indicative of an attempt to restore normal conditions. He believed that the growth of the neuroma ceased with the development of myelin sheaths, but that there was a possibility that growth might continue even after the sheaths developed.

Schuh believed that the scar tissue which develops at the end of a nerve after division gives rise to a certain resistance to the growing or regenerating neuraxes which causes them to leave the straight course which they usually pursue to zigzag in all possible directions, some of them turning back on themselves within their sheaths. The neuroma consists of scar tissue and neurofibrillae which are irregularly interlaced, some of which have more or less completely formed medullary sheaths. The entire process is to be regarded as an attempt at regeneration which has been modified or thwarted by scar tissue. Some of the neuraxes are turned back on themselves, while others interlace or intertwine in the scar tissue in their attempts to pass through it.

Cruveilhier believed that the bulb formed to protect the nerve end, while Billroth thought that the neuroma represented the tissue growth associated with an attempt of the constituents of the central end of the divided nerve to reach the part of the nerve lying opposite and to complete regeneration. Ziegler thought that the neuroma developed as the result of a growth exceeding physiologic limits, a useless, tumor-like formation resulting.

Cone has recently drawn attention to the predominance of nerve fibers in neuromas. According to him, microscopic examination demonstrates that the homogeneous mass consists of interlacing funiculi of young nerves, the funiculi varying from 10 to 50 microns in diameter. Sometimes larger ones are found among these. When one sees larger fibers running parallel and bound together in bundles, they usually belong to the original trunk from which the others spread. As a rule, these are found on one side and away from the tip of the bulb. Sometimes, however, these bundles may be found at the very tip, for the trunk not infrequently coils around as a whole before sprouting at the end.

Small interlacing funiculi are the most characteristic feature of the neuroma, but not infrequently single tendrils growing wild in the surrounding tissues are found. They are varicose, bulbed at the end, they branch frequently and course in a spiral manner. The supporting surrounding tissue is, as a rule, cellular, vascular, wavy connective tissue, not loose areolar tissue. It is rather compact, more so than is usually the case with cellular connective tissue. Cone believes that

many of the spindle-shaped nuclei are derived from the proliferating sheath of Schwann cells. A large number of nuclei are always found among the fibers. Sometimes they are staff-shaped, sometimes they are fusiform. The shape seems to depend somewhat on the stage of regeneration. Cone has frequently seen these so numerous that the section resembled that of a leiomyoma.

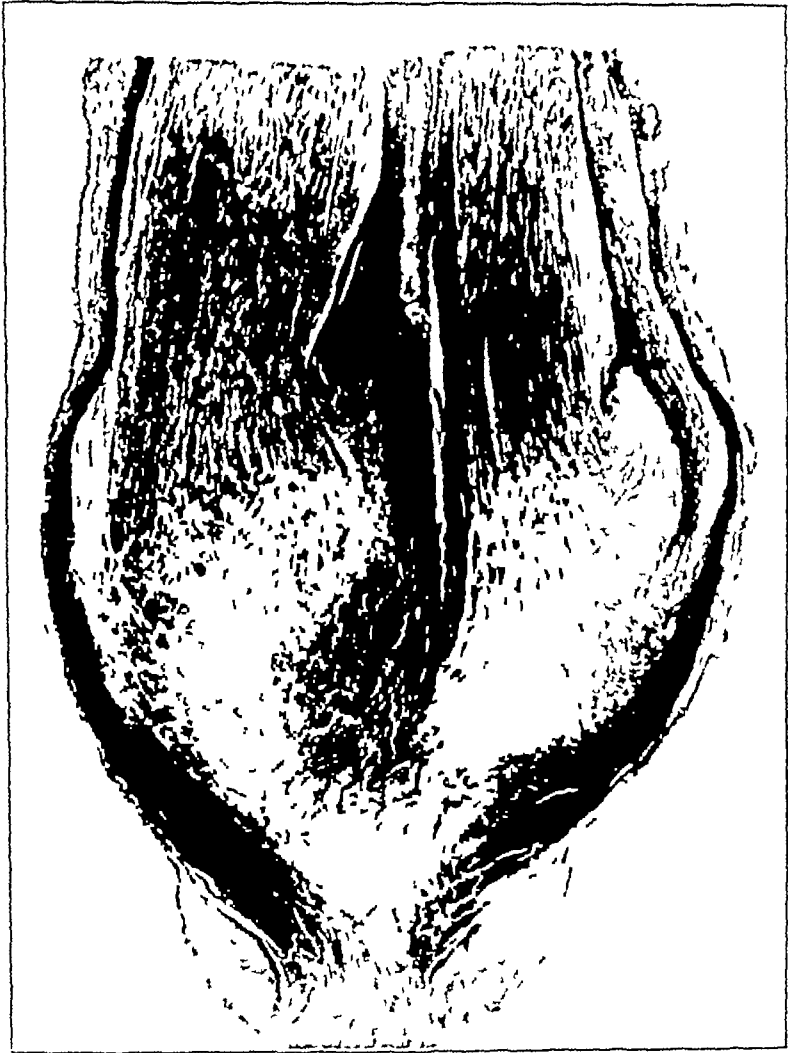


Fig 1—Longitudinal section through typical neuroma showing relation of epineurium and connective or scar tissue cap to the end of the nerve. The straight longitudinal neuraxes may be seen in the proximal part of the neuroma just before they reach scar tissue in the center of the neuroma. Nerve was divided transversely thirty-one days before this specimen was removed.

It can be seen that the opinions which have been expressed concerning the histology of the neuroma vary, and that its significance has been variously interpreted.

Suppuration undoubtedly contributes to their formation as it increases the amount of scar tissue, but even at the present time when sepsis is relatively uncommon neuromas form although many are not associated with spontaneous pain

REPORT OF EXPERIMENTAL WORK

The experimental work, which we report here, had as its first object the determination of the factors which caused neuroma formation and as its second object the prevention of the neuroma

The operations were performed under strict aseptic precautions and the dissections were made along intermuscular septums to avoid hemorrhage. Thus the two factors, suppuration and hemorrhage, to the consequences of which so much importance has been attached in the causation of neuromas, were eliminated. When the nerve was exposed, the sciatic being used in all cases, it was divided transversely by sharp knife or scissors.

In all cases, even when perfect aseptic healing occurred, a neuroma developed. The neuroma was well formed by the nineteenth day after division. The bulbs may vary somewhat in shape, but they tend to become oval or spherical. If the bulb rests on bone or tendon or some resistant tissue, the part of the bulb resting there may be somewhat flattened, while the other parts increase in size. The increase in size takes place where there is the least resistance.

One of us (Lewis) has seen one instance of a divided nerve in a war wound in which the divided ends had been driven into the bone where no neuroma formed, and he believes that in this instance the pressure of the surrounding bone prevented bulb formation, which occurs with such frequency that it might almost be regarded as normal.

Figures 1 and 2 represent the appearance of neuromas after longitudinal section. The neuroma represented in Figure 3 has been cut somewhat obliquely. It, however, did not present the symmetrical enlargement presented by the neuromas represented in Figures 1 and 2.

The gross general characteristics of a neuroma are well represented in Figures 1 and 2. Evidently after a transverse section of a nerve, the funiculi retract within the epineurium. The epineurium contracts down over the cut end of the nerve, but does not completely cover it, for the cut end is covered by a connective tissue cap which becomes continuous on all sides with the epineurium. In Figure 1, this cap seems to be placed on top of the epineurium. This connective tissue cap occurs quite regularly in neuromas. It indicates apparently the site of a blood clot which forms over the end of the nerve after division. This becomes transformed into scar tissue by invasion of connective tissue from tissues surrounding the nerve end, from the endoneurium, perineurium and epineurium. This connective or scar tissue cap does

not block completely developing neuraxes, for in a number of specimens neuraxes which have penetrated this cap are found in the connective tissue lying beyond the nerve

In a microscopic examination of the neuroma, the most striking thing is the spirals which were apparently first described by Perroncito in his experiments dealing with nerve regeneration. These will be described first, for they seem to indicate the factor which is most to be emphasized in neuroma formation



Fig 2—Typical neuroma, presenting pyramidal shaped cap and showing relation of epineurium. Parallel bundles of neuraxes can be seen passing relatively low down in the outer part of the neuroma

A high power representation of a spiral is seen in Figure 5. The growing neuraxes of the regenerating nerve are blocked by connective or scar tissue. They are unable to penetrate this, and they then spiral back within their own sheath, using the original neuraxis of the sheath

as the axis around which they spiral. Developing from the branching neuraxis of this spiral are several end disks. These disks merely represent exaggerated forms of the smaller end bulbs which are observed in nerves undergoing normal regenerative processes. A number of neurofibrillae may develop from each of these disks, or the disk may undergo a degenerative change. The center of a disk may dis-

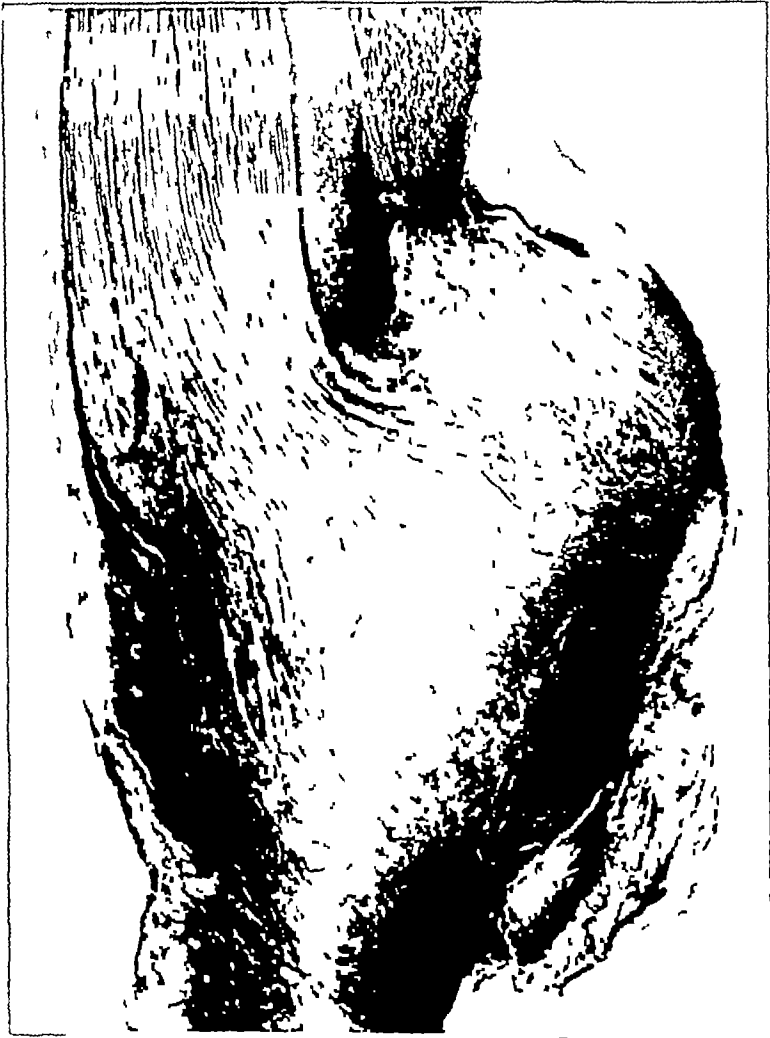


Fig 3—Oblique section of a neuroma which did not have the typical spherical shape. The shape of a neuroma may be modified by pressure. When lying on bone or tendon, it may be flattened while the side enlarges where the resistance is less.

appear, leaving a nerve ring, which was also described by Perroncito, although he does not seem to have thought of the possibility of nerve ring formation as a result of degeneration of the center of a nerve disk.

As a spiral enlarges it may rupture its neurilemmal sheath. It then

comes to be directly in contact with the connective tissue of the neuroma. These spirals we believe to be one of the characteristics of an amputation neuroma in the earlier stages of its formation. They indicate well the growth energy of neurofibrillae stimulated to reproductive activity by division of a nerve.

Figure 4 represents the number of spirals which may be observed in a neuroma. They have no constant position. The spiral represented in Figure 5 was found at the periphery of a neuroma, while the spirals



Fig 4—Group of spirals found in the proximal zone of a neuroma, just at the point where the straight longitudinal neuraxes first meet the connective tissue of the neuroma

represented in Figure 4 were found in the center, in its proximal part where many of the fibers still retained their straight course and were not broken up and dispersed by scar tissue.

Figure 6 represents the dispersion of neuraxes which occurs when the regenerating fibers reach the scar tissue. The neuraxes, which have a fairly straight course, are found in the proximal part of the neuroma. As they approach the neuroma, they become broken up and dispersed. In this instance, which is apparently quite accidental, these fibers bend in toward the center of the neuroma. Some small funiculi

may be seen, but usually the neurofibrillae are so broken up that a funicular arrangement is no longer preserved and the single fibers have an irregular zigzagging course through the scar tissue

Figure 7 is a section through the center of a neuroma. It indicates the irregular distribution of neuraxes in the scar tissue of the neuroma. In this section, there is, however, an attempt at the formation of



Fig 5—High power of a spiral showing neuraxes spiralling back within the neurilemmal sheaths and several large end disks. As the spiral enlarges, it may break through the neurilemmal sheath and come to lie in the connective tissue. The center of these disks may disappear to form a nerve ring.

There is no constant distribution of the different elements as has already been emphasized. A zonal arrangement in the neuroma has, however, been described by some. In all sections, numerous end bulbs and disks indicative of marked attempts at regeneration may be seen.

. The peculiarities of the connective tissue of the neuroma have been noted by many. Figure 8 represents this tissue. It is rather loose and wavy and contains peculiarly shaped cells and fibers which appear to be swollen. It is rather a young connective tissue and remains so for some time. It is quite probable that the developing



Fig 6—Proximal zone of a neuroma. Parallel neuraxes may be seen passing into the beginning of the neuroma. Several small end bulbs and disks may be seen on the neuraxes. The neuraxes become broken up and dispersed and irregularly distributed through the scar tissue.

neuraxes during their regenerative activity stimulate this connective tissue to an excessive growth which continues for some time. In our attempts at prevention of neuroma formation, as will be shown later, it was thought that if the neuraxes could be prevented from regenerating until the tissue which developed in the cut end of the nerve had

become more adult connective or scar tissue, the bulbous enlargement, which is formed largely by developing neuraxes, but also by connective tissue, could be prevented. This loose, vascular tissue is formed by the endoneurium and perineurium, and encloses proliferating cells of the neurilemmal sheaths. It is practically impossible, however, to

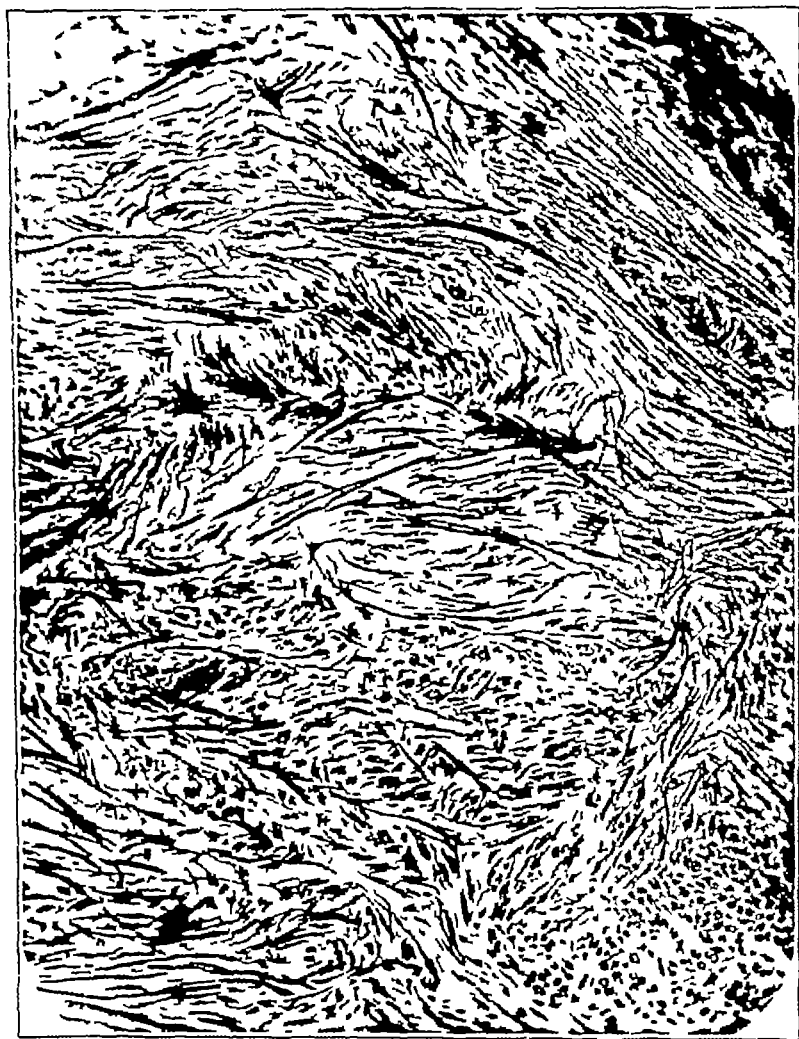


Fig 7—The arrangement of the neuraxes in the center of the neuroma

differentiate the sheath cells from the other cells which form constituent parts of the nerve.

In the older neuromas, as shown in Figure 14, this scar tissue becomes more compact and sclerotic, and in the older neuromas it forms relatively heavy septums which surround and separate neighboring funiculi.

Corner, in discussing neuroma formation, states that divided nerve fibers first degenerate and afterward regenerate, undergoing two

changes, while the connective tissue (endoneurium, perineurium and epineurium) commences at once to repair, undergoing but one change, and that as a result the connective tissue of the nerve gets a considerable regenerative start as compared with the neuraxes. Consequently, in the early stages, according to Corner, the end bulb of a divided nerve consists very largely of fibrous tissue. Into this tissue, the nerve fibers grow. The central part of the end bulb is formed



Fig 8—The character and arrangement of the connective tissue in a neuroma.

from the repairing inner coats of the nerve (the endoneurium and perineurium). Its outer and circumferential parts are largely formed from the outer coat (epineurium). This connective tissue bulb has partly ceased to contract by the time the nerve fibers grow into it by reason of its early start, and it offers a substantial buffer to the regenerating fibers.

The regenerative changes in neuraxes occur much more rapidly than Corner states. Within six hours after division of a nerve, there are definite evidences of regenerative activity on the part of divided neuraxes. Some of these may be abortive, but some are definitive. The changes in the neuraxes and connective tissue occur and progress simultaneously, and it seems certain that the developing neuraxes stimulate the connective tissue to increased and continued growth.

A neuroma indicates an attempt, which is thwarted or blocked by scar tissue, on the part of the neuraxes of a divided nerve to seek the



Fig 9—The character and arrangement of the connective tissue in a neuroma

distal segment and thus complete nerve repair. These regenerating neuraxes then either form spirals or irregularly distributed and dispersed fibers in the bulb. These in their growth stimulate the connective tissue to increased and continued growth.

Any procedure which is employed with the intention of preventing neuroma formation must be directed against the neuraxes rather than against the connective tissue of the end of the nerve.

The following procedure has been employed by us to prevent neuroma formation. After the division, the trunk of the nerve is

injected with absolute alcohol from three-fourths to 1 inch above the plane of section. Enough alcohol is injected to make the nerve appear a dull white, resembling quite a great deal cooked egg albumin. The following experiments are cited to show the effect.

RABBIT 24—Large, full grown, 11 days

March 1, 1918. Left sciatic nerve exposed, large nerve, absolute alcohol injected at several different points. Approximately 25 cm of the nerve was well injected. Nerve cut distal to the points of injection and about 1 cm resected.

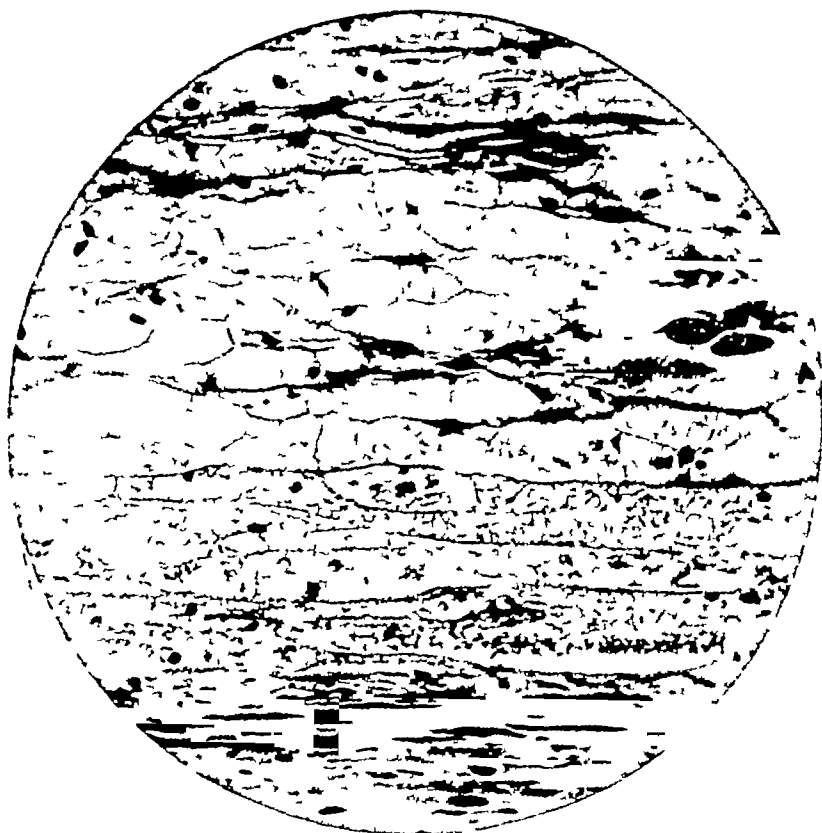


Fig 10—Effects of absolute alcohol injection on the neuraxes. Finely granular material remains of degenerated neuraxes. Neurilemmal sheaths, many of which remain, are filled with granular masses and globules of fat.

March 12. Rabbit killed. Sciatic nerve exposed. Distal end of proximal segment of nerve surrounded by small amount of pus. Nerve end slightly enlarged, and a light yellow. Hemorrhage into nerve trunks, extending for a distance of about 3 cm from end. Central segment removed and fixed in neutral liquor formaldehydi. Tissue stained by the Bielschowsky silver method.

Microscopic Findings. In several series of longitudinal sections of successive levels of the distal end of the proximal segment, the neuraxes in the injected areas are broken up into short irregular segments. The myelin of the fibers is present in the form of a granular detritus and smaller and larger globules. The neurilemmal sheaths appear well preserved. Here and there

irregularly formed cellular elements are found within the neurilemmal sheaths the histogenesis of which cannot be clearly determined

RABBIT 40—Full grown, 18 days

March 5, 1918 Left sciatic nerve exposed Absolute alcohol injected at several points into the internal popliteal divisions Quite a little alcohol escaped into the wound The nerve was cut distal to the points of injection and resected Wound closed

March 23 Rabbit killed Wound well healed On exposing the sciatic nerve, no material increase of connective tissue about the nerve was noted Distal end of the proximal segment tapers to a fine point, which is slightly

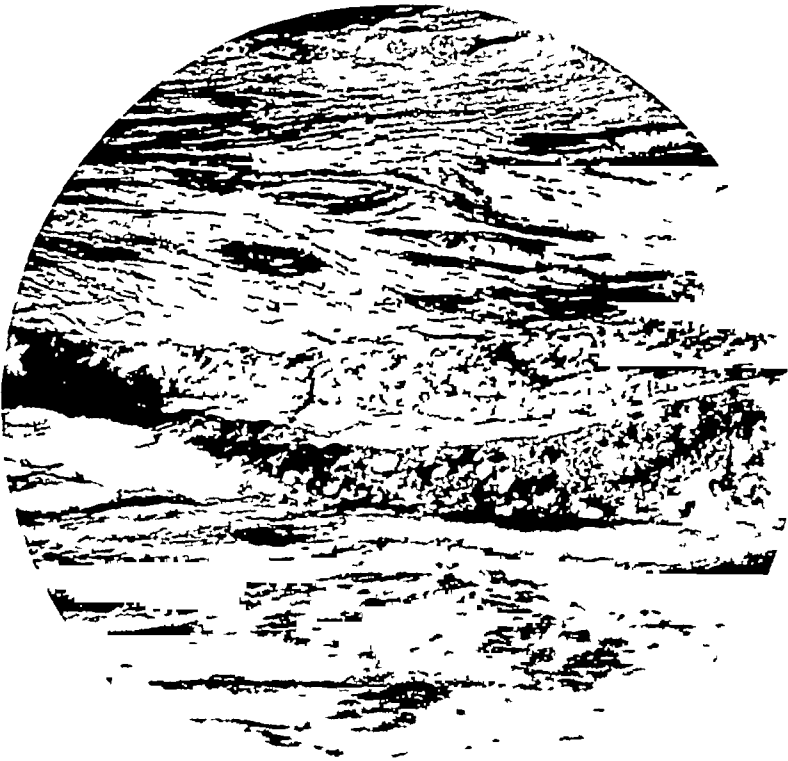


Fig 11—Section of specimen, ninety days after injection Degenerated neuraxes and myelin sheaths may be seen in lower part of the field Straight longitudinal regenerating neuraxes may be seen in upper part No evidences of spiral formation or end disks seen in this section

adherent to the underlying muscle About 25 cm of the proximal segment is a light yellow Proximal sciatic segment removed and fixed in neutral liquor formaldehydi for Bielschowsky silver staining

Microscopic Findings In two series of longitudinal sections of successive levels of the distal end of the proximal segment it can be clearly determined that both of the divisions of the sciatic have been well injected, the alcohol evidently having passed into the main trunk of the nerve Almost all of the neuraxes have been broken up into short segments and granules The myelin has been broken up into a granular detritus The neurilemmal sheaths

are easily made out. In these many spindle-shaped enlargements are found at irregular intervals. Small nuclei, the origin of which is doubtful, are scattered throughout the granular myelin detritus. The fibrous tissue sheaths of the distal end of the proximal sciatic segment appear thickened. Fibrous tissue is found at the cut end of the nerve.

RABBIT 14—Full grown, 20 days

Feb 28, 1918. Left sciatic nerve exposed and injected with absolute



Fig 12—Section of distal end of proximal segment of a rabbit's sciatic nerve, ninety days after injection with absolute alcohol. Tapering end of nerve without any evidence of neuroma formation may be noted. The ends of nerves treated in this way often present in the earlier stages a peculiar yellowish white appearance due to the degenerated myelin.

alcohol, several point injections being made. Very little alcohol escaped into the wound. Nerve cut distal to the points of injection and 1 cm. resected. Wound closed.

March 18. Rabbit found dead. Wound well healed. On exposing the sciatic, the distal end of the proximal segment is found to taper to a fine line.

which is adherent to the underlying muscle. A small blood clot surrounds the distal end of the proximal segment. Proximal segment removed and fixed in neutral liquor formaldehydi. Sections stained in iron-hematoxylin and picrofuchsin.

Microscopic Findings In several series of longitudinal sections made at successive levels the structural appearance is such that the sections would not be recognized as sections of peripheral nerve tissue. Endoneural connective tissue strands and neurilemmal sheaths are the only parts which may be

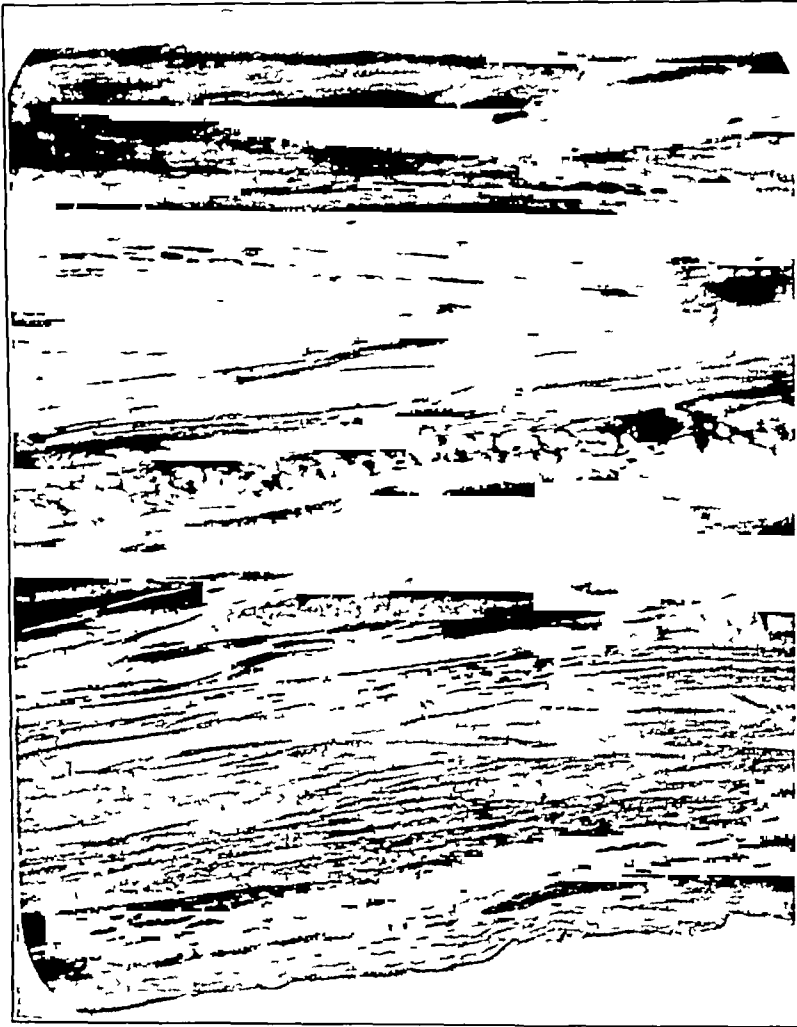


Fig 13—A few neuraxes in injected part of nerve

recognized in the larger internal popliteal bundle. The neuraxes have disappeared completely. The myelin has been broken up into a granular detritus or appears as inclusions in large vesicular cells having very small nuclei. In the external popliteal nerve, not so fully injected, some normal neuraxes are to be found. In others, degenerative changes resembling those occurring in a nerve after division are found. The neurilemmal sheaths of both the internal and external bundles present a structural appearance not unlike that of a normal nerve.

RABBIT 28—Small, half grown, 21 days

March 1, 1918 Left sciatic nerve exposed and injected with absolute alcohol Successful injection, hardly any alcohol escaping Nerve resected distal to the point of injection Wound closed

March 22 Rabbit found dead in the morning Seemed well nourished Wound healed well On exposing the left sciatic nerve, it was found to be slightly adherent to the muscle bed The distal end of the proximal segment tapers for a distance of 15 cm to form a fine strand It is a light yellow Distal end of proximal segment removed and fixed in neutral liquor formaldehyde Sections stained with iron-hematoxylin and picrofuchsin



Fig 14 — Old neuroma with relatively dense sclerotic scar tissue surrounding funiculi The fibers forming these funiculi have for the most part acquired their medullary sheaths

Microscopic Findings In several series of longitudinal sections, including the area of alcohol injection, the perineural sheaths of the funiculi appear slightly thickened The neurilemmal sheaths of the old fibers are present only in part In the areas in which they have disappeared and in some of the distended sheaths are found large vesicular cells, notably compressed, which have granular and globular inclusions The cells have small nuclei Such cells are less numerous in the distal part of the proximal segment The nerve is consequently reduced in size

RABBIT 11—Full grown, 24 days

Feb 26, 1918 Left sciatic nerve exposed and injected with absolute alcohol Resected distal to point of injection

March 22 Rabbit found dead in the morning Seemed well nourished Wound well healed The nerve when exposed was found but slightly adherent to the underlying muscle Distal end of the proximal segment presents tapering end The proximal part of the nerve was removed and fixed in neutral liquor formaldehydi Sections stained with iron-hematoxylin and picrofuchsin

Microscopic Findings In a series of longitudinal sections of the distal end of the proximal segment, including the part injected with absolute alcohol and 2 cm proximal to it Practically all the neurilemmal sheaths are preserved Many of the old neurilemmal sheaths are greatly distended Here and there, they have disappeared In such areas and within certain of the neurilemmal sheaths, large vesicular cells with small nuclei are observed Both of the main bundles are equally affected

RABBIT 1—Large, full grown, 36 days

Feb 18, 1918 Left sciatic nerve exposed and raised from its bed for several centimeters Lifted on hook and injected with absolute alcohol Nerve well injected presenting milky white appearance Resected distal to point of injection

March 26 Rabbit died during morning, still warm when found Much emaciated Abscesses filled with cheesy material found in different parts of body Wound well healed On exposing the sciatic it was found that the external popliteal division of the nerve had not been injected and cut The internal popliteal division was found to have a tapering end Nerve fixed in neutral liquor formaldehydi Bielschowsky silver staining, good differentiation of neuraxes

Microscopic Findings It is evident from a study of several longitudinal sections that the internal popliteal was insufficiently injected, for a large number of the fibers are not affected by the alcohol, showing normal nerve fibers In the part injected, the neuraxes and myelin sheaths have disappeared and are replaced by granular detritus and large vesicular cells with protoplasmic inclusions Perineural connective tissue not materially thickened

RABBIT 21—Full grown, 36 days

Feb 28, 1918 Left sciatic exposed and injected with absolute alcohol Injected in two places 8 mm apart Nerve resected distal to points of injection

April 5 Rabbit found dead in the morning, emaciated, wound well healed On exposing the nerve a discoloration about the distal end of proximal segment (probably due to hemorrhage) was noted The distal end of the proximal segment tapers to nearly a point and is a light yellow About 15 cm proximal to the distal end, the nerve presents a normal appearance Nerve removed and fixed in liquor formaldehydi Sections stained in iron-hematoxylin and picrofuchsin

Microscopic Findings In three series of longitudinal sections taken at successive levels, including about 3 cm of the distal end of the proximal stump, the following observations were made Approximately 2 cm proximal to the place of injection, normal nerve tissue is reached Distal thereto, in progressive degrees, neuraxes and myelin are replaced by granular detritus, globules and phagocytic cells, in part within neurilemmal sheaths, in part in areas in which the neurilemmal sheaths have disappeared, only strands of endoneural connective tissue remaining Down-growing nerve fibers, in part with very thin myelin sheaths, can be traced from the central undegenerated portion into the degenerated area These fibers are found singly or in small bundles, have a very regular course, in the main parallel to the long axis

of the nerve, and reach to within 1 cm of the distal end of the proximal stump. Here and there strands of nucleated bands of syncytial protoplasm are noted in the degenerated portion of the nerve.

RABBIT 2—Large, full grown, 49 days

Feb 18, 1918 Right sciatic exposed, partly freed and injected with absolute alcohol, cut distal to points of injection and resected. Wound closed.

March 18 Wound completely healed, hair growing over shaved area.

April 8 Found dead in the morning. On exposing nerve, it was found that the external popliteal bundle was cut, but that internal was intact. External popliteal presents slight enlargement of distal end of the proximal stump, end tapers to fine strand and is a light yellow. Nerve removed and fixed in neutral liquor formaldehyde. Sections stained in iron-hematoxylin.

Microscopic Findings Only cut external popliteal sectioned. It is evident from a study of a series of longitudinal sections that this branch was but partly injected, for disintegration of neuraxes and myelin sheaths is observed in but a small area. The remainder of the stump resembles closely in structure that of amputation neuroma, with proliferation of connective tissue and down-growing neuraxes. This experiment cannot be regarded as successful.

RABBIT 43—Half grown, 52 days

March 5, 1918 Left sciatic exposed and injected with absolute alcohol, one injection. Quite a little alcohol escaped into wound. Nerve cut and resected. Wound closed.

April 25 Killed. Rabbit in good condition. On exposing nerve, it was found to present normal appearance to about 2.5 cm from distal end of the central stump. Distal end shows a slight spindle-shaped enlargement centralward, then tapers to a fine strand. Streaks of yellow white, parallel to long axis observed. The distal end of the central stump removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained.

Microscopic Findings In three series of longitudinal sections, taken at different levels, it may be observed that in the distal part of the proximal stump to the extent of about 2 cm, the neuraxes and myelin and in part the neurilemmal sheaths of the nerves have been replaced by granular and globular detritus and vesicular cells, arranged in columns or groups, separated by strands of endoneural connective tissue and neurilemma remains. Single neuraxes or small groups of such, growing from the central undegenerated portion of the nerve, can be traced into degenerated area. These neuraxes have a regular course, in the main parallel to the long axis of the nerve. Nucleated protoplasmic strands accompany these neuraxes. In the distalmost part of the central stump as yet no new neuraxes are found, from this part also the granular detritus and vesicular cells have disappeared.

RABBIT 22—Full grown, 56 days

Feb 28, 1918 Left sciatic exposed and injected with absolute alcohol, well injected. Nerve cut distal to field of injection and resected. Wound closed.

April 25 Killed. Rabbit in good condition, slight neurotrophic ulcer, left foot. Wound well healed. On exposing nerve, it is found that it presents a normal appearance to about 1.5 cm from distal end of the proximal stump, which presents only very slight enlargement, is a yellow white and tapers to fine strand, which seems continuous with surrounding connective tissue. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Successful silver differentiation obtained.

Microscopic Findings In three series of longitudinal sections taken at successive levels, it may be observed that numerous new neuraxes growing from the central undegenerated portion of the nerve have grown distally into the portion injected with absolute alcohol. These neuraxes course singly or in small bundles, having in the main a longitudinal course, the small bundles of neuraxes showing here and there an interchange of fibers. Between these neuraxes are found columns or areas of granular detritus and vesicular cells. The down-growing neuraxes have practically reached the distal end of the central stump. There is observed no tangling or crisscrossing of neuraxes as seen in a neuroma, nor is there such an intergrowth of neuraxes and connective tissue as is observed at the end of a neuroma.

RABBIT 41—Large, full grown, 58 days

March 5, 1918 Left sciatic exposed and internal and external popliteal bundles injected separately, the former is injected in two places, well injected. Nerve cut distal to point of injection and 1 cm. resected. Wound closed.

May 3 Rabbit found dead in the morning. Neurotrophic changes, left heel, popliteal lymph gland enlarged. On exposing the nerve, it is found that the central stump tapers to fine strand, and is a light yellow. About 2 cm. proximal to distal end of central stump nerve presents normal appearance, with funiculi distinct. Nerve removed and fixed in Fleming chrom-osmic-acetic solution. Sections stained in safranin and light grün.

Microscopic Findings In three series of longitudinal sections taken at successive levels, it may be observed, beginning with the most distally placed series, that the neuraxes and myelin of the nerve fibers of both of the main funiculi have entirely disappeared. Fine strands of endoneural connective tissue and neurilemmal sheaths remain forming a very open meshed network, surrounding areas of granular and globular detritus, through which are scattered small round or oval nuclei. In the series of the next higher level, the same general structure is found for the greater part of the section. In the more central portion of the sections, small strands of syncytial nucleated bands of protoplasm are observed, which become more numerous in the centrally placed of the three series. These nucleated protoplasmic bands have grown into the degenerated portion of the nerve from the central undegenerated portion.

RABBIT 38—Nearly full grown, 63 days

March 5, 1918 Left sciatic exposed, quite a little bleeding, controlled. Two injections of absolute alcohol made, both bundles injected. Nerve cut and 5 mm. resected. Wound closed.

May 13 Rabbit found dead in the morning, in fairly good condition. On exposing the nerve, distal end of proximal stump is found tapering to fine strand slightly adherent to muscle bed. The distal end for a distance of about 2 cm. is a light yellow, central to this nerve has normal appearance. Nerve removed and fixed in neutral liquor formaldehydi. Sections stained in iron-hematoxylin and picrofuchsin.

Microscopic Findings In several series of longitudinal sections taken at successive levels, it is observed that in the distal end of the central stump, in the area of the alcohol injection, neuraxes and myelin of the nerve fibers have entirely disappeared, fine strands of endoneural connective tissue and remnants of neurilemmal sheaths remaining. This portion of the nerve consists almost wholly of granular and globular detritus, surrounded by the perineuronal sheaths. More proximalward in the series of sections, nucleated

protoplasmic bands growing distally from the undegenerated central nerve are to be observed, to one side, near the perineural sheath, these protoplasmic bands extend distally to near the distal end of the central stump

RABBIT 18—Full grown, 65 days

Feb 27, 1918 Left sciatic exposed, large vein cut, clamped Absolute alcohol injected and nerve cut just distal to injected field and resected Wound closed

May 5 Found dead in the morning Protocol incomplete, simple statement, "No neuroma"

RABBIT 10—Full grown, 71 days

Feb 26, 1918 Left sciatic exposed and injected with absolute alcohol Nerve cut distal to field of injection, 1 cm resected Wound closed

May 8 Killed Rabbit not in good condition, emaciated, "fungus" ears On exposing the left sciatic the proximal stump is found to end in a fine tapering strand, not especially adherent to the muscle bed, of light yellow About 2 cm proximal to the distal end, nerve presents the appearance of normal nerve The nerve removed and fixed in ammoniated alcohol for pyridin silver stainings Very good differential silver staining obtained

Microscopic Findings From the microscopic appearances presented in the several series of longitudinal sections taken at successive levels it is evident that the injection of alcohol was not wholly successful in this experiment Numerous neuraxes may be traced from the central portion of the nerve toward the end of the proximal stump, numerous large end disks are found at various levels Especially to one side of the nerve, and about 2 mm from its distal end, numerous complex spirals of neuraxes are to be observed At the distal end of the proximal stump, crossing and recrossing of neuraxes are observed, though there is not observed that intergrowth of neuraxes and connective tissue such as is generally seen in a neuroma In the entire series of sections, few remains of myelin and neuraxes of the old nerve fibers are observed The conclusion seems warranted that at the time of operation the nerve trunk was partially injected with absolute alcohol and that after section of the nerve a partial neuroma developed

RABBIT 32—Full grown, 80 days

March 4, 1918 Left sciatic exposed Several injections of absolute alcohol made, spaced at intervals of about 5 mm Well injected Nerve resected 13 cm just distal to field of injection Wound closed

May 23 Killed Rabbit in good condition, severe neurotrophic changes, left hind foot On exposing left sciatic, it was found to present a normal appearance to within 2 cm of distal end of central stump The end presents first a slight enlargement then tapers to a fine strand only loosely adherent to the surrounding connective tissue Distal nerve segment completely degenerated Central sciatic removed and fixed in ammoniated alcohol for pyridin silver staining Good differential silver staining obtained

Microscopic Findings Three series of longitudinal sections and one series of cross sections were made Sections were made of approximately 3 cm of the distal end of the proximal sciatic stump The most centrally placed sections include a portion of the normal nerve Numerous down-growing neuraxes may be traced from this portion of the nerve into that portion immediately influenced by the absolute alcohol In the latter portion areas and columns of globular and granular detritus are found, coursing between which there may be observed smaller and larger bundles of neuraxes, which

have in the main a regular course, with here and there an interchange of fibers. These down-growing neuraxes may be traced to the distal end of the proximal stump, but present no tangling or intertwining as observed in a neuroma. The perineural sheath surrounds these down-growing neuraxes.

RABBIT 26—Full grown, 83 days

March 1, 1918. Left sciatic exposed and injected with absolute alcohol. Well injected. Nerve cut distal to field of injection and 8 mm. resected. Wound closed.

May 23. Killed. Rabbit in good condition. On exposing the left sciatic, it was found to present normal appearance to within 2 cm. of distal end of central stump. Distal end of central stump presents slight enlargement then tapers to fine strand, adherent to underlying muscle. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings. In two series of longitudinal sections in which approximately 4 cm. of nerve is sectioned, it is observed that numerous neuraxes growing distalward from the central uninjured portion of the nerve extend into the portion affected by the absolute alcohol. These neuraxes are enclosed within the thickened perineural and epineural sheaths and have in the main a longitudinal course, except those found in close proximity to the fibrous sheaths, many of them cross and recross and intertwine on the inner surface of the perineural sheath. These down-growing neuraxes can be traced to the attenuated end of the proximal stump. The remains of the fibers affected by the absolute alcohol are found in areas of granular detritus, interspersed with large vesicular cells, and fat cells, between which course the neuraxes.

RABBIT 29—Full grown, 83 days

March 1, 1918. Left sciatic exposed and injected with absolute alcohol, well injected. Nerve cut distal to field of injection and resected. Wound closed.

May 23. Rabbit found dead in the morning. Left femur found broken, apparently some days before death. On exposing the sciatic, tissues about nerve found much congested and containing extravasated blood, owing to fracture. The distal end of the central sciatic found to taper to fine strand, relations not clear owing to extravasated blood. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings. In two series of longitudinal sections including approximately 4 cm. of the distal end of the proximal stump, large number of down-growing neuraxes may be traced from the uninjured central portion of the nerve to its distal end. These neuraxes are enclosed in the thickened fibrous tissue sheaths of the nerve and have in the main a regular course. Within the area injected with absolute alcohol, a few columns and areas of granular detritus, certain large vesicular cells and many fat cells are found. Such columns and areas are separated by bundles of down-growing neuraxes, a few of which cross such fields either as single fibers or as small bundles of such.

RABBIT 17—Nearly full grown, 84 days

Feb. 27, 1918. Left sciatic exposed and injected with absolute alcohol. First injection not successful, nerve slightly torn. Second attempt at a higher level, was successful, well injected. Nerve cut and resected. Wound closed.

May 22 Rabbit found dead in the morning, seemed in good condition, severe neurotrophic changes, left hind foot. On exposing the left sciatic, the distal end of the proximal stump is found to taper to a fine strand, adherent to the underlying muscle. Several delicate nerve bundles appear to extend on the muscle bed for a distance of about 1 cm beyond the cut end of the nerve. No evidence of a neuroma noted. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained. A portion of the nerve removed in this experiment was lost, the portion at hand represents the most distal portion of the central stump for the length of a little over 1 cm.

Microscopic Findings In a series of longitudinal sections, small bundles of fine neuraxes, enclosed within the thickened fibrous sheath are observed. These bundles of neuraxes are found separated by areas of granular detritus and fat cells.

RABBIT 42—Half grown, 84 days

March 5, 1918 Left sciatic exposed and injected with absolute alcohol, larger bundle in two stages, smaller bundle, one injection. Well injected. Nerve cut and 1 cm resected. Wound closed.

May 29 Rabbit found dead in the morning. Protocol incomplete. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings In three series of longitudinal and cross sections in which approximately 4 cm of nerve was cut, central neuraxes are found passing distalward through the area injected with absolute alcohol and have reached the distal end of the proximal stump, and as scattered neuraxes or as small bundles of such can be traced into the connective tissue overlying the muscle bed for a distance of about 1 cm beyond the cut end of the nerve. In the main, these neuraxes have a very regular longitudinal course. Very little detritus, the remains of the injured nerve fibers are found in the area injected with absolute alcohol.

RABBIT 8—Full grown, 90 days

Feb 23, 1918 Left sciatic exposed and injected with absolute alcohol, well injected. Nerve cut just distal to injection, 1 cm resected. Wound closed.

May 23 Killed. Rabbit very much emaciated, severe neurotrophic changes of foot, two toes missing, large ulcer on heel. On exposing the sciatic, this is found of normal appearance to about 15 cm from end of proximal stump. End of stump presents slight enlargement then tapers to a fine strand. This nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Faint, but differential neuraxes staining obtained.

Microscopic Findings In three series of longitudinal and one of cross sections, taking in a little over 4 cm of the distal end of the nerve, the following may be observed. Neuraxes in large numbers can be traced from the proximal practically uninjured portion of the nerve, through the area affected by the alcohol to the distal end of the proximal stump. In a series of cross sections, taken about 2 cm above the point of puncture for alcohol injection, the funicular structure of the nerve is not lost, the perineural sheaths are distinctly thickened. Within the funiculi, numerous neuraxes seen in cross section, four to ten within one neurilemmal sheath. Not all of the funiculi are equally affected. In the more distal portion of the nerve, in two series of longitudinal sections, numerous neuraxes, having in the main a longitudinal course, and arranged in larger or smaller bundles, and separated

by elongated areas and columns of granular detritus, vesicular cells and fat cells are to be observed, enclosed within the thickened fibrous sheaths

RABBIT 37—Full grown, 93 days

March 5, 1918 Left sciatic exposed and injected with absolute alcohol, both bundles well injected Nerve cut about 5 mm distal to place of injection and 1 cm resected A small amount of alcohol escaped into the wound Wound closed

June 6 Killed Rabbit in fair condition, neurotrophic ulcer on left heel On exposing the sciatic nerve it is found to present normal appearance to near end of distal stump which tapers to a fine strand Nerve removed and fixed in Fleming's chrom-osmic-acetic mixture Sections stained with safranin and light green In several series of cross and longitudinal sections made from the distal 4 cm of the proximal stump, the following observations are made In the series of longitudinal sections small bundles composed of nucleated protoplasmic bands and fine myelinated nerve fibers may be traced from the central normal portion of the nerve to the end of the distal stump Between these there are found broader or narrower columns composed, in the main, of large vesicular cells with small nuclei, having globular and granular protoplasmic inclusions These cells would appear to have phagocytized the remains of the nerve fibers affected by the absolute alcohol The fibrous sheaths of the distal end of the central stump are found materially thickened In the distal 15 cm the funicular structure of the nerve trunk is lost

RABBIT 34—Full grown, 94 days

March 4, 1918 The left sciatic exposed and injected with absolute alcohol, well injected Nerve cut 5 mm distal to place of injection and 1 cm resected Wound closed

June 5 Killed Much emaciated, severe neurotrophic ulcer, left heel On exposing the left sciatic nerve it is found normal to within 15 cm of end of the proximal stump It presents a slight enlargement then tapers to fine strand, adherent to the underlying muscles Nerve removed and fixed in neutral liquor formaldehydi Sections stained in iron-hematoxylin and picrofuchsin Tissue not well embedded, sections torn

Microscopic Findings In the sections remaining it can be determined that nucleated protoplasmic bands extend from the proximal undegenerated portion of the nerve to the distal end of the proximal stump These bands of nucleated protoplasm may be regarded as non-myelinated fibers Between such bands or bundles are found columns or long spindle shaped areas of large closely arranged vesicular cells with globular or granular inclusions

RABBIT 39—Small rabbit, not full grown, 95 days

March 5, 1918 Left sciatic exposed, free venous bleeding Absolute alcohol injected, large bundle in several places, smaller bundle, one injection Well injected A small amount of alcohol escaped into wound Wound closed

June 8 Rabbit found dead in the morning On exposing the left sciatic, it presents a normal appearance to within a short distance of the distal end of the proximal stump which tapers to a fine strand Nerve removed and fixed in ammoniated alcohol for pyridin silver staining Silver differentiation is not successful

Microscopic Findings Several series of longitudinal sections, though not showing differentiation of neuraxes, are sufficiently stained to admit of the interpretation that there was no neuroma formation The arrangement of the connective tissue warrants this conclusion

RABBIT 27—Full grown, 97 days

March 1, 1918 Left sciatic exposed and injected with absolute alcohol. On first attempt, movement of animal prevented successful injection, on second trial successful injection was made. Nerve cut distal to point of injection and resected.

June 6 Killed Rabbit in good condition. On exposing the left sciatic nerve it presents normal appearance to near distal end of the proximal stump which appears to end in fine tapering strand. The relations of distal end of proximal stump is not clearly made out owing to presence of dense cicatricial tissue at end of the fine tapering strand. Nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Fairly good silver differentiation obtained, sheath nuclei as well as neuraxes stained.

Microscopic Findings Several series of longitudinal sections made. In these, it is possible to trace numerous neuraxes from the more centrally placed sections, through the field affected by the alcohol injection to the distal end of the proximal stump. At the distal end of the proximal stump the neuraxes were found to cross and recross, especially those found in close relation to the outer fibrous sheath. In the more central portion, the neuraxes present a more regular longitudinal course. In this portion of the nerve, between small bundles of neuraxes, large spindle-shaped areas composed of vesicular cells and granular detritus are to be found. In relation with the distal end of the proximal stump, there was noted at the time the nerve was removed a small irregular mass about 5 mm in diameter which appeared to consist of dense fibrous tissue. In sections, this mass was found to contain a nucleus of osseous tissue surrounded by dense fibrous tissue. In this fibrous layer mainly to one side, several small bundles of neuraxes were found. A study of this series of sections suggests imperfect alcohol injection and as a result partial neuroma formation, with proliferation of fibrous tissue consequent to escape of alcohol into the wound.

RABBIT 15—Full grown, 102 days

Feb 26, 1918 Left sciatic exposed and injected with absolute alcohol, nerve cut distal to injection and 1 cm resected. Wound closed.

June 8 Killed Animal not in good condition, severe neurotrophic ulcer on left heel, popliteal lymph gland greatly enlarged. On exposing the left sciatic, the central stump is found tapering to fine strand, distal end a light yellow. Connective tissue in proximal part of popliteal space quite dense. Proximal sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained, especially in more central portion of nerve.

Microscopic Findings Two series of longitudinal sections including the 2 cm of the distal end of the central stump made. In the more distally placed series, within the thickened fibrous sheath, a granular detritus and vesicular cells occupy nearly the entire area. No down-growing neuraxes appear to have reached this portion of the proximal stump. In the more centrally placed series, numerous new neuraxes are found. Those more axially placed have a regular course, those more peripherally placed criss-cross on the inner surface of the fibrous tissue but do not present the intergrowth of fibrous tissue and neuraxes as noted at the distal end of a neuroma.

RABBIT 3—Large, full grown, 108 days

Feb 18, 1918 Left sciatic exposed and injected with absolute alcohol. Nerve cut about 5 mm distal to place of injection, not resected. Wound closed.

June 6 Killed Left hind foot, slight neurotrophic changes on heel. On

exposing the sciatic, it is found that the external popliteal was not cut, and probably not injected. Internal popliteal central stump presents a tapering end. Some delicate fine strands seem to extend beyond the cut end, on cutting these "fibers," no twitching of calf muscles observed. The nerve removed and fixed in ammoniated alcohol for pyridin silver staining. Good silver differentiation obtained.

Microscopic Findings Section of the noncut and noninjected external popliteal made with the cut and injected internal popliteal, cut together in series of longitudinal sections. In the sections, the external popliteal presents the appearance of a normal nerve, here and there a few degenerated fibers are noted. In the distal end of proximal stump of the internal popliteal, central down-growing neuraxes can be traced to the distal end, having in the main a regular longitudinal course, and separated into smaller and larger bundles by long spindle-shaped areas, occupied by granular detritus and large vesicular cells. A few neuraxes can be traced into the connective tissue surrounding the distal end of the central stump of the internal popliteal.

RABBIT 25—Half-grown rabbit, 150 days

March 1, 1918. Left sciatic exposed and injected with absolute alcohol. Well injected, practically no alcohol escaped to the wound. Sciatic cut 5 mm distal to place of injection and 1 cm resected. Wound closed.

July 30. Killed. Rabbit not in good condition. On exposing the left sciatic, the proximal stump is found to end in a fine tapering strand. No bulb. No nerve fibers could be traced beyond the cut end of the nerve. Proximal part of sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Good differential silver staining obtained. During embedding the end of the central sciatic stump became bent, so that it was not possible to cut longitudinal sections including the entire length of the piece.

Microscopic Findings It is evident from a study of the entire series, that down-growing neuraxes coming from the central uninjected portion of the nerve, have passed through the area injected with absolute alcohol and have reached the distal end of the central sciatic stump. These neuraxes have in the main a longitudinal course. Toward the distal end, some crisscrossing of neuraxes is observed, not to the extent found in a neuroma, and such crisscrossing of neuraxes as is observed occurs within the fibrous tissue sheath and mainly on its inner surface.

RABBIT 23—Nearly full grown, 157 days

March 1, 1918. Left sciatic exposed and injected with absolute alcohol. Well injected. A small quantity of alcohol escaped into the wound. Nerve cut just distal to place of injection and resected. Wound closed.

August 5. Killed. Rabbit in good condition, foot missing, stump completely healed. On exposing the sciatic the central stump is found to end in fine tapering strand from the distal end of which a fine filament can be traced toward the distal sciatic stump, but does not reach it. Calf and foot flexor muscles completely degenerated. Central sciatic removed and fixed in ammoniated alcohol for pyridin silver staining. Not wholly successful differentiation obtained, patchy.

Microscopic Findings In a fairly complete series of longitudinal sections, taking in the distal 2 cm of the central sciatic stump it may be observed that numerous neuraxes both myelinated and nonmyelinated grow distal through the field of alcohol injection to the extreme distal end of the central stump. Here the connective tissue sheath of the nerve is found very materially thick-

ened, the connective tissue extending into the interior of the nerve end and separating the nerves into small intertwining bundles. More centrally the neuraxes have a more regular longitudinal course, except those found in close relation to the fibrous tissue sheath which course along the inner surface of the sheath without definite arrangement. The structural appearances presented are not those of a neuroma.

COMMENT

The microscopic findings in the distal end of the proximal segment 157 days after alcohol injection are interesting and instructive. By this time numerous neuraxes, both myelinated and nonmyelinated, have passed through the injected part of the nerve to the extreme distal end of the proximal segment. The connective tissue sheath of the nerve is very materially thickened at this point. It extends into the interior of the nerve and separates it into small intertwining bundles. More centrally the neuraxes have a more regular longitudinal course, except those in close relation to the fibrous sheath which course along the inner surface of the sheath without definite arrangement. The structural appearances presented are not those of a neuroma.

These findings are in marked contrast to those noted after operations — recognized surgical procedures — which are performed on the end of the nerve. These operations are the so-called swing door and the crush and tie. We shall quote but two typical examples of these.

Serial sections of this specimen removed two weeks after the swing door operation revealed fairly dense fibrous tissue over the end of the nerve. Distinct neuroma structure is found in the distal end of the proximal segment. At the end of the nerve, just proximal to the fibrous cap, many interlacing newly-formed neuraxes are found in the fibrous tissue. Some of the developing neuraxes are growing into the connective tissue distal to the end of the proximal segment. Many spirals are found at all levels in the series in the part undergoing neuroma formation.

Four weeks after the "swing door," or reversed V, operation, the typical neuroma structure is found. The pyramidal fibrous cap, spirals with interlacing neuraxes and much fibrous tissue are observed. Small bundles of neuraxes with a more regular course are found distal to the area in which the interlacing neuraxes are so numerous. The large number of end disks indicate actively proliferating fibers. There are a good many spirals. These are mostly grouped in several areas.

Four weeks after the crush and tie operation, a distinct neuroma picture is found. The distal end of the proximal segment has a relatively long connective tissue cap, which is pyramidal in shape. The newly formed neuraxes have grown into this long connective tissue

cap In the region just proximal to this scar tissue there is a marked interlacing of new-formed neuraxes in the fibrous tissue. Many spirals are found in the various fields.

These two operations, which are recommended and employed in clinical surgery, do not prevent neuroma formation. While the neuroma seems to form a little more slowly after the crush and tie operation, it is well formed even after this operation at the end of four weeks.

Even as early as one week after these operations there are distinct evidences of neuroma formation indicated by the development of end disks and spirals which indicate a connective or scar tissue block.

An objection has been raised against the injection of alcohol with the view of preventing neuroma formation. It has been claimed that the alcohol may escape into the surrounding tissues and increase the amount of scar tissue. The surrounding tissues may be easily protected from the alcohol, little, if any, of which escapes if the injection is carefully made. We have observed no marked increase in the amount of scar tissue after its use, and have never observed the formation of a neuroma at the site of injection.

CONCLUSIONS

1 A neuroma indicates an attempt which is thwarted or blocked by scar tissue on the part of the neuraxes of a divided nerve to seek the distal segment and thus complete nerve repair.

2 When blocked the regenerating neuraxes form spirals and end disks, and become irregularly dispersed throughout the connective tissue of the bulb.

3 The regenerating neuraxes react on the connective tissue elements of the bulb, which as a consequence increase in number and maintain their embryonal characteristics longer than is normally the case.

4 The "swing door," or reversed V, operation and crush and tie operation do not prevent neuroma formation.

5 Any method to be successful must be directed against the neuraxes.

6 Absolute alcohol injected into the nerve some distance (from three-fourths to 1 inch) above the plane of section is more successful in preventing neuroma formation than any of the other methods ordinarily employed.

POSTOPERATIVE PULMONARY COMPLICATIONS *

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INTRODUCTION Importance of subject Apparent increase in incidence due to better records

REVIEW OF LITERATURE Dearth of American and English studies Statistical tables Irritation vs embolism as contributing causes The rôle of the anesthetic

PRESENTATION OF MATERIAL Fifty-five complications, eleven deaths in 1,562 operations Division into groups Discussion of groups

GENERAL DISCUSSION General factors, age, incidence by seasons, relation to kind of anesthesia The part chilling, trauma, general condition, anesthesia, preexisting pulmonary disease and sepsis play Discussion of the mechanism of embolism

SUMMARY AND CONCLUSIONS Embolism the chief factor Prophylaxis by selection of cases, reduction of sepsis and trauma and careful anesthesia

INTRODUCTION

In the last twenty years with the rapid development of surgery, its spread to ever widening fields and the brilliancy of many of its therapeutic results, much of the wholesome respect for the dangers involved in even a simple operation, which lay so heavy on our forebears, has disappeared. There seems to be an increasing tendency toward surgical therapeutics which now and then leads even the wisest and most experienced surgeons to operate without sufficiently deliberate and careful study. The confessions of the late Maurice Richardson¹ regarding this tendency serve to indicate some lamentable mistakes that ensue, and a study such as the present one points out additional dangers that are just as serious.

It is only in the last few years that the increasing and careful analysis of end-results has brought home again the very certain dangers that accompany all surgical interventions. The medical student is likely to think that with the operation the major part of the treatment ends, but the experienced surgeon realizes that then the difficulties and dangers often commence. Those few surgeons who have deliberately submitted their results to searching public and private scrutiny have convincingly shown that an improvement in results and technic and a steady decrease in postoperative difficulties is an inevit-

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1 Richardson Boston M & S J 159 711-716, 752-756, 791-795, 1908

able consequence. The lessons such analyses have pointed out have always made for progress. Surgeons must frequently balance their accounts if they are to find the small mistakes. Bad results are overlooked or forgotten when such studies are not made, and yet the seriousness of such complications as this study presents cannot be overestimated. There can be no greater calamity than to have an apparently healthy patient succumb after a relatively simple operation.

A previous study in this field by one of us in collaboration with J. J. Morton² made it evident that the risks involved in even simple operations were sufficient to cause hesitation, and gave us a desire to find a means for doing away with such risks. There are many dangers in surgery, some immediate, some coincident with the operation, some that arise during the convalescence. The immediate dangers concern technic, the late are more obscure, less spectacular and often chronic, so that less attention has been paid to them. Yet they are by no means unimportant, and, indeed, at times are the cause of death. Of these dangers, postoperative pulmonary disorders should occupy a relatively prominent position, since they are by no means infrequent, often they are most alarming, and at times they are fatal. Our first study in 1916 at the Massachusetts General Hospital was so instructive that we were anxious to repeat it in another institution, to prove our conceptions and if possible to establish further methods of prophylaxis.

There have been from time to time careful studies of this group of cases, and with each successive study the proportion of complications has reached a higher percentage. This is the result not of an increasing incidence, but of more careful study. Whipple,³ in his second study in this field, which he confines to the pneumonia group alone, reported that at the Presbyterian Hospital, New York, in 1898, an analysis of these complications by Schultze⁴ gave 0.38 per cent (twenty-two pneumonias in 5,724 anesthetics), whereas in 1913-1914 (Whipple⁵) the figure was 2.2 per cent (42 pneumonias in 1,902 anesthetics), and in 1915-1916 (Whipple³) the figure was 2.6 per cent (ninety-seven cases in 3,719 anesthetics). Our own studies show a postoperative pulmonary complication of 1.86 per cent in our first paper, and of 3.52 per cent in this study. Our figures are for total pulmonary complications, Whipple's for pneumonia only. For pneumonia alone our figure reaches 1.6 per cent. The increasing percentage

² Cutler, E. C., and Morton, J. J. *Surg. Gynec. & Obst.* 25: 621 (Dec.) 1917.

³ Whipple, A. O. *Surg. Gynec. & Obst.* 26: 29 (Jan.) 1918.

⁴ Schultze. *Med. and Surg. Reports* Presbyterian Hospital, New York, January, 1898.

⁵ Whipple, A. O. *Med. Rec.* 89: 581 1916.

must be well understood or one would deduce an increasing amount of disability. A comparison of the mortality figures brings the real situation to light, in our first paper of 1915-1919, the mortality percentage of morbidity was 507, in this study, 1919, it is 20, a very creditable improvement. Even so, the figures, untranslated, are misleading. The material available for study in this report was far more accurate and full, anesthesia charts accompanied all histories, and the preoperative and postoperative findings were more elaborately recorded. We were able, therefore, to assemble a proportionately far larger number of cases since the minor pleurisy and bronchitis cases were all carefully described. Even so, the morbidity and mortality figures are sufficient to cause concern.

We have again taken the whole field of postoperative pulmonary complications rather than a single group, partly because the groups are closely allied, and the study of one group helps in a realization of the etiologic factors in the others, but chiefly because the lesson is more sharply indicated by the exposition of this very similarity of etiology and, therefore, similarity of prevention. Not only the nature of all the complications from anatomic, therapeutic and prophylactic phases, groups them into a single category, but the reason for their occurrence is frequently, even in different groups, through the same mechanism.

A study of the reports made in this field both abroad and in America will convince all that the anesthetic is not the chief factor. Ether pneumonia is, therefore, a very misleading term. There is little doubt that the irritation caused by the anesthetic plays some part, but never the major part.

Our first study led us to lay most stress on the preoperative condition, especially on a preoperative pulmonary lesion, also on the amount of infection present and the proximity of the operative field to the lungs. The present study, which is based on a far more reliable mass of material, although emphasizing many of the deductions in our previous paper, seems to point out that the chief factor is embolism, a finding in agreement with much of the work of previous investigators. The importance of preexisting sepsis is thus seen in a new light, and as will be pointed out later in this study our conclusions are supported by more certain facts. Again, we would emphasize that the anesthetic is not the chief factor, and certainly all surgeons have seen numerous badly administered anesthetics, with blue, "wet" patients, coughing or even vomiting during the period of anesthesia, and yet noticed that no postoperative pulmonary complication has ensued. Indeed, it is the very safety of the anesthesia which has led many astray, since the attribution of the postoperative pulmonary disabilities to such an

evident etiology would seem entirely natural. Again, it is no uncommon thing for a surgeon to remove the appendix, on a mistaken diagnosis, from a patient with unrecognized pneumonia and see absolutely no deleterious effects from the anesthesia. Lastly, the incidence of such a complication under local anesthesia is often very high. Henle,⁶ for example, reports more complications with local than after any one of the general anesthetics.

This study was undertaken in an effort to improve the methods and results in this hospital, and it brought to light, to our surprise, a larger number of untoward results than we had suspected. And yet, the mortality figures for pneumonia (0.51 per cent) are comparable to the lowest figures reported from other clinics with the exception of the Mayo Clinic report for 1913,⁷ when they reported no deaths, an isolated and inexplicable fact. We have arbitrarily studied the cases submitted to operation in a single year, 1919. During that period there were 2,032 surgical admissions, 1,929 of these were submitted to some sort of intervention in the operating room. Of these, however, only 1,562 were actually submitted to surgical operative procedures under an anesthetic. The cystoscopies, dressings, plaster casts and allied procedures are not included in the 1,562 cases used as the basis for this study. Of these 1,562 patients, fifty-five (3.52 per cent) developed a definite postoperative pulmonary complication which we have divided into the following groups: lobar pneumonia, bronchopneumonia, bronchitis, pleurisy, empyema, lung abscess, pulmonary embolism and cases showing an exacerbation of a preexisting tuberculous condition after operation. Of these fifty-five patients, eleven died, a mortality percentage of 0.70 for the total number of postoperative complications, and a mortality percentage of the morbidity of 20.0. This is a relatively low figure in comparison to other statistics from general surgical clinics.

It is essential, in order to use statistics, that all conditions be the same, but in medicine this is almost impossible, as no two clinics treat the same type of patient. Thus, we think it unfair to compare our figures with those from clinics where a minimum septic and traumatic work is done and where the clientele is to a large extent drawn either from the country folk or from patients from a distance, which at once eliminates the serious acute surgical emergencies. Any patient who can travel from 200 to 1,000 miles by train must at least be a fairly good risk. The larger number of our patients are drawn from a large city and have neither hereditary nor environmental advantages.

6 Henle. *Verhandl. d. deutsch. Gesellsch. f. Chir.* 30:240, 1901.

7 Beckman, E. H. *Collected Papers Mayo Clinic*, Philadelphia, W. B. Saunders Company, 1913, p. 776.

and are to a considerable extent emergency or traumatic cases. Also, we have taken the whole field of postoperative pulmonary complications, so that only such studies as the previous communication from the Massachusetts General Hospital² and Armstrong's⁸ from the Montreal General Hospital are suitable for comparison. Our pneumonia figures, however, can be compared to the very numerous contributions in this single field.

We are strongly of the opinion that the anesthetic is never the primary and sole cause of the ensuing complication and invite a careful study of our cases with this point in view. A study of the preoperative risk chiefly in regard to sepsis, preexisting pathologic condition of the lung or general debility, old age or poor circulation will reveal many important factors. Operative trauma, the position of the wound as regards mobility of the part, the position of the patient on the table, and the anesthesia will now and then rise in their importance in relation to the resulting pulmonary disability.

REVIEW OF THE LITERATURE

Unfortunately, this subject has not until recently received much attention in American and English medical literature, although many workers in German clinics, more than a decade ago, discussed the subject thoroughly, notably, Ranzi,⁹ Otte,¹⁰ Laewen,¹¹ Bibergeil,¹² Pfannenstiel,¹³ Kroenlein,¹⁴ Henle,⁹ Mikulicz,¹⁵ von Lichtenberg,¹⁶ Czerny¹⁷ and Kelling.¹⁸ Just why such an important field has been neglected one cannot say, since it is one of the fields in which the great calamities of surgery occur. It is especially difficult to find studies covering the whole field of postoperative complications, although there exist many studies in the various groups of such complications, particularly studies on postoperative pneumonia.

Table 1 shows an average morbidity of 2.12 per cent with a mortality percentage of morbidity of 25.2, including the Mayo figures for 1913, when there were no deaths reported. Since the deaths

8 Armstrong Brit M J **1** 1141, 1906

9 Ranzi Arch f klin Chir **87** 380, 1908

10 Otte Munchen med Wehnschr **54** 2473, 1907

11 Laewen Zentralbl f Chir **4** 96, 1907, Beitr z klin Chir **50** 2, 1906

12 Bibergeil Arch f klin Chir **78** 339, 1905

13 Pfannenstiel Zentralbl f Gynäk, 1903, No 1

14 Kroenlein Verhandl d deutsch Gesellsch f Chir **34** 131, 1905

15 Mikulicz Verhandl d deutsch Gesellsch f Chir **30** 560, 1901

16 Von Lichtenberg, A Munchen med Wehnschr **53** 2286, 1906, Zentralbl f d Grenzgeb d Med u Chir **11** 129, 1908

17 Czerny Verhandl d deutsch Gesellsch f Chir **34** 109, 1905

18 Kelling Verhandl d deutsch Gesellsch f Chir **34** 136, 1905

occur almost entirely in the pneumonia and pulmonary embolism groups, it is natural that more interest should be displayed in such studies, and we find many and excellent discussions, particularly of the pneumonia group. The total statistics, however, are impressive and would seem to indicate that approximately one patient in every fifty operated on will develop a lung complication, and one in every 185 will die from some such complication.

TABLE 1—GENERAL SURGERY—ALL LUNG COMPLICATIONS

Clinic	Author	Reference	No of Cases	Pulmonary Morbidity		Pulmonary Mortality		Mor- tality % of Mor- bidity
				No	Per Cent	No	Per Cent	
Mayo*	Beckman	Collected Papers Mayo Clinic, 1910, p 594	3 657	41	1 12	9	0 24	21 9
Mayo*	Beckman	Collected Papers Mayo Clinic, 1912, p 738	5 835	92	1 57	6	0 10	6 5
Mayo	Beckman	Collected Papers Mayo Clinic, 1913, p 776	6,825	87	1 27	0	0 00	0 0
Von Elselsberg	Ranzi	Arch f Klin Chir 57: 380 1908	6 871	263	3 8	†	†	†
Montreal General Hospital	Armstrong	Brit M J 1 1141 1906	2,500	55	2 2	32	1 28	58 1
Massachusetts General Hospital	Cutler and Morton	Surg Gynee & Obst 25: 621 (Dec) 1917	3,490	65	1 86	33	0 94	50 7
Osnabrueck	Otte	München med Wehn schr 54 2473, 1907	7 years total cases 2,000†		†	†	†	†
	Pfannenstell	Zentralbl f Gynäk., 1903, No 1			§	§	§	§
Combined Statistics	von Lichten- berg	Centralbl f d Grenz- geb d Med u Chir 11 129, 1908	23 673	440	1 9			
Peter Bent Brigham Hospital	Cutler and Hunt		1 562	55	3 52	11	0 7	20 0

* Amended to include pulmonary embolism

† Not recorded for whole series

‡ No lung complications

§ No deaths from lung complications No pneumonia

The condensed comparison of statistics given in Table 2 demonstrates the seriousness of this complication and shows well the increase in morbidity due to more careful study in the later reports with the resultant fall in the mortality figures. The comparison with Osler and McCrae's¹⁹ combined statistics is only further evidence of the fallacy of simple statistics and undoubtedly the sources of their facts were relatively incomplete studies. The mortality figures compare better with Osler and McCrae's¹⁹ estimate of a 53 per cent mortality in pneumonia in the physically infirm. This is interesting in the light of recent studies on pneumococcus types. Whipple²

¹⁹ Osler, William and McCrae, Thomas. Modern Medicine, Philadelphia Lea and Febiger, 1913, 1 202

has shown that the predominant type in postoperative pneumonia is the Group IV pneumococcus, which agrees with Stillman's²⁰ findings that it is commonly present in healthy mouths, but Dochez and Cole²¹ have demonstrated its relatively low virulence. The work of Wadsworth,²² showing that infection in pneumonia depends on the virulence of the organism versus the resistance of the body, is merely an elaboration of now well known facts, and the findings by Whipple that the predominant organisms belong in Group IV is to us evidence

TABLE 2—GENERAL SURGERY — POSTOPERATIVE PNEUMONIA

Clinic	Author	Reference	No of Cases	Pneumonia Morbidity		Pneumonia Mortality		Mortality % of Morbidity
				No	Per Cent	No	Per Cent	
Mayo	Beckman	Collected Papers Mayo Clinic 1910, p 594	3 657	10	0 27	5	0 14	50 0
Mayo	Beckman	Collected Papers Mayo Clinic 1912, p 738	5 835	19	0 32	6	0 10	31 5
Mayo	Beckman	Collected Papers Mayo Clinic 1913, p 776	6,825	27	0 39	0	0 00	0 0
Roosevelt Hospital, N Y	Booth	Med Rec SO 582 1916	2 612	23	0 9	7	0 26	30 4
New York Hospital	Burnham	Surg Gynec & Obst 19 468, 1914	1,413	15	1 06	7	0 50	46 6
Massachusetts General Hospital	Cutler and Morton	Surg Gynec & Obst 25 621 (Dec) 1917	3 490	40	1 14	22	0 63	55 0
Montreal General Hospital	Armstrong	Brit M J 1 1141, 1906	2 500	30	1 20	22	0 88	73 3
Lelpzig	Laewen	Zentralbl f Chir 4 96, 1907	9,755	180	1 8	113	1 15	63 0
Presbyterian Hospital	Whipple	Surg Gynec & Obst 26 29 (Jan) 1918	3 719	97	2 60	25	0 67	25 6
Peter Bent Brigham Hospital	Cutler and Hunt		1 562	25	1 6	8	0 51	32 0
		Totals	41 368	466	1 12	215	0 41	46 1
	Osler and McOrae	Modern Medicine, 1 202, 1918	130 101	499	0 35			

that we must look further than some simple irritative phenomenon for the etiologic factor. This we firmly believe, and our investigation this time seems to demonstrate additional factors to our findings and conclusions drawn from a previous study in 1916.

Among the studies of postoperative pneumonia are many reports on the occurrence of pneumonia after laparotomy, and the increased incidence in this field is very striking.

20 Stillman, E. G. J. Exper. Med. **24** 651 (Dec) 1916.

21 Dochez and Cole, in Forchheimer's Therapeutics of Internal Diseases, New York, D. Appleton & Co., 1914, **5** 470.

22 Wadsworth. Am. J. M. Sc. **127** 851, 1904.

The average morbidity of pneumonia in laparotomies shown in Table 3 is further substantiated in other reports in which the actual number of laparotomies performed is not given. Thus, in Whipple's last paper,⁸ of the ninety-seven postoperative pneumonias, eighty-eight occurred in patients on whom celiotomy had been performed. Certainly, the comparison with general surgery is striking. Thus the pneumonia morbidity for general surgery is 1.12 per cent compared with 4.4 per cent for laparotomies.

TABLE 3—LAPAROTOMIES—PNEUMONIAS (POSTOPERATIVE)

Clinic	Author	Reference	Number of Cases	Morbidity	
				No.	Per Cent
Zurich	Kroenlein	Verhandl. d. deutsch. Gesellsch. f. Chir. 34 181, 1905	1,409	8	0.56
Massachusetts Gen. Hosp.	Cutler and Morton	Surg. Gynec. & Obst. 25 621 (Dec.) 1917	1,181	20	1.7
Breslau	Kausch	Verhandl. d. deutsch. Gesellsch. f. Chir. 34 117, 1905	1,881	45	2.4
Hamburg	Kuemmel	Verhandl. d. deutsch. Gesellsch. f. Chir. 34 118, 1905	1,754	43	2.5
Berlin	Bibergeil	Arch. f. klin. Chir. 78 339, 1905	3,909	135	3.5
Heidelberg	Czerny	Verhandl. d. deutsch. Gesellsch. f. Chir. 34 109, 1905	1,302	52	3.9
Lipzig	Laewen	Beitr. z. klin. Chir. 50 2, 1906	1,829	98	5.4
Munich	Gebele	Beitr. z. klin. Chir. 43 2, 1904	1,196	77	6.43
Breslau	Henle	Verhandl. d. deutsch. Gesellsch. f. Chir. 30 240, 1901	1,787	143	8.0
Königsberg	Wolff	Deutsch. Ztschr. f. Chir. 88 71, 1907	971	121	12.5
Peter Bent Brigham Hosp.	Cutler and Hunt		856	21	2.4
Average morbidity					4.48

There has been much discussion of the etiologic factors. The most emphasized factor is the presence of sepsis and the easy pathways to the lung and pleural cavity both by the blood vessels and the lymphatics. In addition, hypostasis, due to confinement to bed, is increased by the unconscious splinting of the abdominal wall through partial inhibition of diaphragmatic movements. Further, the motion which does occur is likely to set free minute thrombi in the operative field, especially if there has been much trauma, and cause small pulmonary emboli. Still further, laparotomy exposes surfaces unused to the outer world, and evaporation and chilling take place easily. Bibergeil¹² and Kelling¹³ especially emphasize the rôle of sepsis, and Armstrong⁸ is impressed particularly with the effect of chilling.

Pulmonary complications most frequently occur after operations involving the epigastrium. In our former study² the percentage of total pulmonary complications in the upper abdominal cases rose to 7.7, and Laewen²³ reported 8.1 per cent in this field. In this study the epigastric operations showed a postoperative pulmonary morbidity of 8.0 per cent. The etiologic factors just mentioned are only further

²³ Laewen. Footnote 11, second reference.

emphasized by all workers in this field. The brilliant anatomic work of Sabin²⁴ demonstrates the ease with which lymphatic channels may carry sepsis or emboli from the epigastrium, and the reports of Kelling,¹⁸ Gee and Horder,²⁵ Bibergeil,¹² Laewen,¹¹ Homans²⁶ and others all emphasize the possibility of such emboli occurring. With a preexisting sepsis, the result is too evident. Possibly this is rather startling to those unaccustomed to summarize results, for, as we pointed out in a former paper, it is in this field that the best surgeons do the majority of the work. The less experienced surgeons may possibly undertake pelvic surgery or the removal of the appendix, but when it comes to the gallbladder and stomach they feel the need of a consultant. And yet the etiology is obvious: first, the possibility of sepsis, next the perfect systems of drainage to the lungs, then the hypostasis increased by protective muscle spasm and dressings, and, lastly, the constantly moving field to loosen up thrombi! We consider that such thrombi or agglutinated masses occur both in veins and lymphatics, and in speaking of embolism we mean the transmission of such masses to the lungs both by venous and lymphatic channels. In view of the subsequent corroboration, Ranzi's⁹ insistence in 1908 on the embolic nature of pulmonary complications was most creditable.

The only other pulmonary complication which has received any great amount of attention is the group of pulmonary embolism of which the high fatality and terrifying clinical picture forces its recognition and importance. Ranzi⁹ of Vienna, Kelly of Baltimore and Wilson²⁷ of the Mayo Clinic have discussed this group very thoroughly, and all agree on sepsis and vascular trauma as the important etiologic factors. The average of the three studies just mentioned shows that pulmonary embolism occurred once in every 744 operations, whereas in this report it occurred once in every 521 cases in which operation was performed.

In 1914, Burnham²⁸ presented a most interesting study on pleurisy and empyema from the Presbyterian Hospital, New York. In 13,013 operations, pleurisy, either dry or with effusion, occurred fifty-nine times (0.45 per cent) with one fatality. Empyema occurred six times and was fatal in each instance. Burnham believes this is characteristic of postoperative empyemas. The etiology of these conditions is seen at once when we study the individual cases. Thus all of the

24 Sabin, F. R. *Science* **44** (N. S.) 145, 1916.

25 Gee and Horder, in Allbutt and Rolleston's *System of Medicine*, New York, the Macmillan Company, 1910, 5:536.

26 Homans, J. *Johns Hopkins Hosp. Bull.* **20** 125, 1909.

27 Wilson. *Collected Papers Mayo Clinic*, Philadelphia, W. B. Saunders Company 1912, p. 727.

28 Burnham. *Surg., Gynec. & Obst.* **19** 468, 1914.

empyemas followed abdominal operations for either local or general peritonitis, and the great majority of the pleurisy cases also followed abdominal operations in the presence of infection

This report of Burnham's points the advantage of analyzing together all pulmonary complications, for each group throws much light on the others. One of the outstanding factors in the etiology of these complications is sepsis. It is no exaggeration to say that some degree of infection was present in the field of operation in 75 per cent of all cases in this study in which pleurisy, empyema, pulmonary embolism or pneumonia developed. The route by which sepsis is transferred to the pleural cavity or lung varies in different cases, but its very presence emphasizes the part the circulation, either vascular or lymphatic, must play in its transportation. The embolic theory is only further substantiated by such evidence.

We have recently seen a striking example. For several days, a vigorous man had been suffering from a scalp infection, and twenty-four hours before death an area from 4 to 5 inches in diameter, the seat of a staphylococcal cellulitis, had been excised down to the cranial bones. At necropsy, the lungs showed minute abscesses, some on the pleural surface. Several of these had ruptured, a fibrinopurulent pleuritis resulting. In this particular instance, the infection was terminal, of course, but it demonstrates the method of pulmonary infection.

The Rôle of the Anesthetic in Postoperative Pulmonary Complications—For years, the term "ether pneumonia" has been used and still is used to apply to postoperative pulmonary disorders. This is unfortunate, since it unjustly lays blame on the anesthetic. Henle,²⁹ Gottstein³⁰ and Mikulicz³¹ reported more pulmonary complications under local anesthesia than under general inhalation anesthesia, and the experimental work of Poppert,³⁰ Offergeld,³¹ Hoelscher³² and of Ladd and Osgood³³ demonstrates that ether when well given by the open drop method cannot be considered as a real factor in resulting pulmonary lesions. These investigators only confirm the clinical experience of such authorities as Bevan,³⁴ Keen,³⁵ Herb³⁶ and Gatch.³⁷

29 Gottstein Arch f klin Chir **57** 409, 1898

30 Poppert Deutsch Ztschr f Chir **67** 505, 1902

31 Offergeld Arch f klin Chir **83** 505, 1907

32 Hoelscher Arch f klin Chir **57** 175, 1898

33 Ladd, W. E., and Osgood G. Ann Surg **46** 460 (Sept.) 1907

34 Bevan, A. D. Tr Am Surg A **33** 21 1915, *ibid* **29** 177, 1911

35 Keen Boston M & S J **173** 831 1915

36 Herb I. C. Ether Simplicity in Its Administration, J A M A **66** 1376 (April 29) 1916

37 Gatch Tr Am Surg A **29** 196 1911

that the irritant action of ether vapor varies with its concentration and that when the anesthetic is given in closed masks and carelessly the aspiration of mucus may be a factor in postoperative lung complications, but that in good and expert hands it is safe and rarely at fault. And yet, how seldom it is in expert hands! Surely, the majority of all anesthetics are given by the house officers or nurses in hospitals, or in private practice, except in the larger centers, by the family physician whose training has not been extensive. Such being the case, if poorly administered anesthesia was the cause of pulmonary complication, why do we not see it more frequently? Consider how often all experienced surgeons have seen badly anesthetized patients make an uneventful recovery. And further, let us recall the days when ether inhalations were given for consumption! There is, indeed, scant evidence to support the view that these postoperative pulmonary complications are due to the anesthetic except in those cases with a definite preoperative pathologic condition of the lung.

Our first paper in 1915 and Whipple's second paper in 1918 reported a higher percentage of pulmonary complications in the winter months. We will show later in this analysis the same tendency. It is well known that simple pneumonia occurs more frequently in the winter months (Osler³⁸), and yet no satisfactory explanation of this has been given, for in some consistently cold climates the percentage is low, and again in Southern districts it is very high.

There has been much conflicting experimental evidence to show the effect of chilling with reduction of body temperature in the etiology of respiratory infections (Marchand,³⁹ Miller and Noble,⁴⁰ Hill⁴¹). The recent work of Mudd and Grant⁴² would seem to show that chilling plays an important role in allowing bacteria which are always present to get a start. And the clinical experience of such authorities as Bibergeil,¹² Kelling¹⁸ and Armstrong⁶ led them to state that chilling of the internal body cavity by cool packs during operation was one of the important factors in the causation of these postoperative lung complications.

The recent interest shown in the effect of atmospheric humidity in steam heated buildings has led us to doubt much of the experimental and clinical evidence presented as to the part chilling alone plays

38 Osler, William. *Principles and Practice of Medicine*, New York, D Appleton & Co., 1910.

39 Krehl and Marchand. *Handb der Allgem Pathologie*, Leipzig, Hirzel, 1908, 1 108.

40 Miller, J. A., and Noble, W. C. *J Exper Med* 24 223 (Sept.) 1916.

41 Hill. *Brit Med Research Committee*, 1919, S. R. Series 32.

42 Mudd, S., and Grant, S. B. *J M Research* 40 53 (May) 1919.

The papers of Ellsworth Huntington⁴³ are enlightening along these lines. His studies would seem to show that it is the dryness and not the coldness of the air which is the important factor. External air has a wide variation, but approximately 70 per cent can be taken as a satisfactory average of humidity, whereas in heated buildings it drops to 25 or 30 per cent. Moreover, with the humidity at 70 per cent, we can be quite comfortable in temperatures near 60 F, although in our houses in winter we demand at least 70 F. The mortality statistics Huntington presents are very suggestive and throw light on the relation to chilling. For example, Mudd and Stewart cooled themselves before an electric fan while stripped, and breathing deeply with their mouths open. This probably produced an excessive dryness in their throats and prevented the action of immune substances. Possibly in this small field itself, we can obviate serious consequences by early inhalation of vapors and a correction of the humidity in our operative recovery rooms.

We agree with Whipple³ that the type of pathologic pulmonary condition in many cases resembles that described by Woillez,⁴⁴ being an acute diffuse lesion, but as we will show later we do not think the anesthetic alone is responsible for this. Group IV organisms are common in the mouths of healthy people (Stillman²⁰), but postoperative pneumonia even when the anesthetic is poorly administered is uncommon. There must be something beyond the simple irritation of the anesthetic and the humidity or chilling to bring about so much definite pulmonary disease. And again, how would this affect operations under local anesthesia? A great number of observers and investigators, including Henderson,⁴⁵ Boothby,⁴⁶ Magaw,⁴⁷ Kelling⁴⁸ and Mortimer,⁴⁸ believe the anesthesia plays a minor rôle, and we find ourselves in agreement with them.

PRESENTATION OF MATERIAL

This study covers all surgical cases admitted to this hospital in the year 1919. During this period there were 2,032 total surgical admissions, but actual operations under an anesthetic were performed on only 1,562 patients. The other 470 patients either were not operated

43 Huntington E. *Mod Med* 1 13 (May) 1919, *ibid* 14 10 (May) 1920.

44 Woillez. *Traité cliniques des maladies aiguës des organes respiratoire*, Paris 1872.

45 Henderson. *Collected Papers Mayo Clinic, Philadelphia* W. B. Saunders Company, 1913 p. 701.

46 Boothby, W. M. *Team Work*, *J. A. M. A.* 67 539 (Aug. 12) 1916, *J. Pharmacol. & Exper. Therap.* 5 379, 1914.

47 Magaw. *Surg. Gynec. & Obst.* 3 795 1906.

48 Mortimer. *Med. Press* 1919 N. S., CVIII 505.

on or were submitted to some simple procedure without an anesthetic, as cystoscopy or the application of a plaster cast. Among these cases, no pulmonary complications arose during the patients' stay in the hospital, which is evidence that the pulmonary complications occurring among surgical patients is in some way directly referable to the operative procedure.

Of these 1,562 patients, fifty-five, or 3.52 per cent, developed a definite postoperative lung disorder. We have summarized these cases in Table 4, and classified them as pneumonia, bronchitis, pleurisy, lung abscess, empyema or pulmonary embolism. In addition, we have taken the cases of pulmonary tuberculosis that showed a serious exacerbation of the disease after operation, whether recognized before operation or afterward. The cases in which a pulmonary lesion (pneumonia) brought about operation through mistaken diagnosis and also the cases in which operation was performed for lung abscess and empyema are discussed, but are not included among the fifty-five postoperative lung complications. Among these fifty-five cases, there were eleven deaths, 0.7 per cent mortality for all operated cases and a mortality percentage of morbidity of 20. This means that approximately one in every twenty-eight patients operated on will have a pulmonary complication, and that one in every 142 will die of such a complication. Such figures, which appear to be true for all clinics, are most disconcerting, but they are nevertheless incontrovertible.

It is true that statistics often lead to false assumptions, and in our problem a thorough understanding of the reasons underlying the operation in each case must be grasped. Thus, emergency cases may demand immediate operation despite the risk of a serious pulmonary complication. Again, it must be remembered that in a great number of fatalities due to various factors, pneumonia will be found at necropsy. Cases in which the lung condition is terminal and not the chief cause of death have occurred several times in this group studied, but these cases are not included as postoperative complications. A patient with diffuse general peritonitis who dies evidently from the peritoneal intoxication and infection may have a terminal pneumonia which, however, is not to be considered as a postoperative complication.

To be sure of our figures every one of the 2,032 histories was carefully gone over, the clinical charts and postoperative notes were studied in order that all cases should be included. We believe that our high postoperative pulmonary morbidity (3.52 per cent) is due to the fact that our figures are really very accurate because of the careful records and abundant postoperative notes, for in a teaching hospital, the histories are elaborate and the postoperative care a constant source of discussion. Without this added attention many of the simpler complications, such as pleurisy and bronchitis, may be entirely neglected in the postoperative notes, even if observed.

Having found a number of lung complications, there is a further difficulty in classifying them. The line between pneumonia and bronchitis is not always clear. This is another reason for studying the groups together as an entire anatomic division and not merely the pneumonias alone or embolism alone.

Pneumonia—As previously stated, and in agreement with other investigators in this field,⁴⁹ the great proportion of serious postoperative pulmonary complications fall into the pneumonia group. Thus, we have twenty-five pneumonias in fifty-five total pulmonary complications of 1,562 operations, or almost 50 per cent of all the complications, and eight, or 72.7 per cent, of the eleven fatalities. It is probable, also, that we have classified among our bronchitis cases some mild pneumonias. Especially may this be true when we realize the atypical picture and clinical course often presented by the postoperative type of pneumonia and the obscuring of any of these symptoms by other postoperative difficulties. The latter are legion. The rise in respiratory rate in practically all upper abdominal incisions owing to an attempt on the part of the patient to retard movement by shallow respiration, when further complicated by a rise in temperature due to wound sepsis or primary sepsis, and finally some resultant hypostatic congestion at the lung bases, are but a few of them. We have taken as the criteria necessary to include a case as postoperative pneumonia, definite physical signs, such as dulness, bronchial breathing and râles, with the accompanying rise in pulse, temperature and respirations, often cyanosis and sometimes pain and chill with onset.

Lobar Pneumonia—A small percentage, only four cases (7.2 per cent) of our pulmonary complications were of the lobar pneumonia type. This is in conformity with our opinion as to the general etiology of such complications which result as a rule in the bronchopneumonia type. In fact, the morbidity percentage of lobar pneumonia in relation to the total number of operations is 0.25 per cent as opposed to a morbidity percentage for bronchopneumonia of 1.34, or five times as frequent. All patients recovered. The ages ranged from 22 to 40, and, with one exception, the patients were considered good risks. In three cases ether was used, in one gas-oxygen, there were no protracted operations. All four patients developed acute symptoms within twenty-four hours, with elevation of pulse, temperature and respirations and the physical signs of beginning consolidation. Recovery in all cases occurred after an average of seven days. One patient, after a normal period of twenty-four hours suddenly had a reinfection, and all the

⁴⁹ Lord, F. T. in discussion on Robinson Samuel Thoracic Diseases I. A. M. A. 67:556 (Aug. 19) 1916. Footnotes 3, 9 and 16 second reference.

TABLE 4—POSTOPERATIVE LOWAR PNEUMONIA

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation, Position on Table	Anesthetic, Kind, Amount, Duration of Anesthesia	Postoperative Course, Pathology
1	9750 N P ♂, 22 January	Inguinal hernia, bilateral	Well developed and fairly well nourished, 137 pounds, heart normal, right chest normal, left chest, base posteriorly, an area of rather harsh breathing, white blood cells 10,000, blood pressure 125/75	Repair Supine position	ether (drop) 9 ounces, well taken, became light and coughed in middle of operation anesthesia, 1 hour 20 minutes, operation 1 hour 15 minutes	In 24 hours, consolidation, right base, dulness, rales increase in whispered voice, 48 hours, bloody sputum, cough, fall of temperature by lysis, normal 5th day discharged well 17th day
2	10173 M M N ♀, 40 March	Cholecystitis, acute, empyema of gallbladder, cholelithiasis	Well developed and nourished, sick appearing, in distress rapid respiration, frequent colds and bronchitis chronic yellow sputum left chest normal, right chest, dulness whispered and spoken voice moderately increased heart normal, weight 135 pounds, blood pressure 120/90	(1) Cholecystectomy and pendicectomy, incidental, accidental cholelithiasis, drainage (2) Repair of common bile duct, drainage Supine position	(1) Ether (drop) 7½ ounces, well taken anesthesia, 1 hour 30 minutes, operation 1 hour 35 minutes (2) Gas-ether (drop) 7 ounces well taken anesthesia 2 hours 10 minutes operation, 2 hours 5 minutes	(1) Stormy recovery pain in chest and cough, abrupt rise of temperature, pulse and respirations, 48 hours, dulness, bronchial breathing, right base rusty sputum increasing symptoms, temperature dropped by lysis 11th day normal, 24 hours later 103 F., signs and symptoms of re-infection same area but not so marked returned to normal by lysis 23d to 29th day (2) Immediate postoperative rise in temperature, pulse and respiration for 4 days no absolute sign of pulmonary involvement, discharged well 24 days later
3	10210 H K ♀, 30 March	Salpingitis, bilateral, acute	Powerfully developed obese 200 pounds, heart and lungs negative, teeth fairly good blood pressure 120/80 history of morning cough for several years, considerable yellow sputum, frequent colds occasional night sweats and chills moderate dyspnea on exertion	Bilateral salpingectomy drainage for acute pelvic peritonitis ventral suspension appendectomy, incidental Trendelenburg position	ether (drop) 4 ounces, anesthesia 1 hour 5 minutes operation 1 hour 3 minutes hysterical, vomited toward close of induction	Fair recovery dyspnea pain in back consolidation of right chest in front, high pitched breath sounds and crackling rales, left chest, respiratory note accentuated moist rales, 24 hour postoperative cough highest temperature 102.4 F., dropped by lysis to normal the 5th day, discharged well 20th day
4	10547 A S ♂, 28 May	Nephroptosis, left	Well developed and nourished 124 pounds (average 140) heart and lungs negative blood pressure, 110/60	Exploration of left kidney, partial decapsulation and nephropexy Right lumbar position	Gas oxygen anesthesia 1 hour 10 minutes operation 1 hour 30 minutes quiet throughout pulse and respirations unchanged	Good recovery rapid rise in temperature, pulse and respiration in 24 hours, temperature 103.6 F. pulse 143, respirations 40 signs of consolidation, right base, sputum negative for tuberculois, white blood cells on 10th day 12,000 recovery by lysis 11th day discharged well 10th day after operation

* In this and the following tables, ♂ represents male, and ♀ female

signs of pneumonia returned. The explanation of reinfection in simple pneumonia is not clear, and in the type under discussion is even more difficult.

Because of the greater frequency of the bronchopneumonic type, an especially careful study of the signs and symptoms in these four cases was made, but they appeared to be decidedly of true lobar type. The explanation for the complication in Case 2 is not difficult, and the preoperative examination undoubtedly made the surgeon anxious on this very score. The patient was 40 years old, gave a history of chronic cough with sputum, susceptibility to bronchitis and moreover there were definite signs of an already existing pulmonary disorder. In addition, the operative field was the epigastrium and sepsis was present. The ease with which organisms could reach the lungs either by embolism or by direct lymphatic extension is too evident. A pulmonary complication was to be expected. In the other cases, there is no such definite preexisting pathologic condition of the lungs, although Case 3 gave a history of night sweats, chills and morning productive cough. Also, the pelvis in this case presented a focus of acute inflammation from which bacteria could be spread and a difficult anesthesia undoubtedly played a part. In Case 1, the patient was an excellent risk, the operation was performed rapidly and without accident or anesthetic difficulty. It is such cases that need the closest scrutiny if we are to find any explanation for the resultant pneumonia. The clinical picture of pneumonia was classical, and our difficulty lies in determining its etiology. The spitting up of bright blood may be interpreted as the evidence of an early embolus from the operative field, probably while still under anesthesia, as there was no history of pain. The prompt recovery aids this explanation in that the lesion was due more to a change of circulatory pressures and congestion than to a true infective process. It is just this type of complication that demands explanation above all others. The anesthesia was well given and well taken, and there were no technical difficulties. The complicating lesion was discrete and localized, and we felt at the time that an aseptic embolus had been set free from the operative field, probably during operation, and had lodged in the lung. Since it was sterile, recovery from it was rapid. In Case 4 the explanation rests (1) on the juxtaposition of the operative field to the pleura, and (2) on the mobility of the part. It seems probable that in the manipulation of a kidney operation there is some trauma through the diaphragm to the lung; if, in addition to this, minute emboli are showered in and hypostasis occurs enough consolidation results to give the signs of pneumonia.

TABLE 5—BRONCHOPNEUMONIA

Case	Surg No Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation, Position on Table	Anesthesia, Kind Amount Duration of Anesthesia Duration of Operation	Postoperative Course, Pathology
1	9767 M F Q. 13 January 6 15 p m	Appendicitis acute perfo ration peritonitis	Well developed and nourished heart and lungs negative, three-day symptoms on ad mission, temperature 101.4 F, pulse 170, respirations 26 white blood cells 23,000	Appendectomy, drain age Supine position (fore- noon after admission)	Ether (drop) 7½ ounces anesthesia, 45 minutes, operation 50 minutes, quiet, color good, pulse very rapid 200	Good recovery Fowler's position, at 4 p m tem perature 101 F, pulse 165, respiration 45 exam- ination of chest 48 hours after operation ques- tionable bronchial breathing, left base, tempera- ture pulse and respiration still high no pain in chest or cough, moderate drainage, tempera- ture, pulse and respiration continued elevated but general condition improving 19th day after operation, suddenly became cyanotic and dysp- neic examination of chest, bronchial breathing both backs more marked on left scattered moist râles, died 2 days later, 22d day after operation Necropsy bronchopneumonia, sepsis from peritonitis general peritonitis, confluent bronchopneumonia
2	9798 J W Q. 28 January	Cholecystitis chronic cho lithiasis	Well developed, obese heart soft, systolic murmur at base lungs negative blood pres- sure 118/80 history of some dyspnea and palpitation	Cholecystectomy chole docostomy Supine position	Ether (drop) 16 ounces anesthesia, 2 hours 15 minutes operation 2 hours 10 minutes, pulse and respirations high difficult to relax mark- ed nausea and vomit- ing when conscious	Stormy recovery patient very intolerant of pain second day after operation temperature 102 F, pulse 110 respirations 10 chest not examined no cough temperature pulse and respirations remained high five days and dropped by lysis to normal 20th day no wound sepsis discharged well 5th day
3	10020 J Mc Q. 23 February	Inguinal hernia left	Well developed and nourished heart and lungs negative pharynx injected tempera- ture 99 F subject to 'chronic cold' abscess at root of tooth which discharges at intervals	Repair Supine position	Ether (drop) ¾ ounces anesthesia 20 minutes operation, 25 minutes well taken, conscious when returned to bed	Good recovery 24 hours later, temperature 102 F, some pain in chest and cough respirations 28-45 temperature 99 to 102 F pulse 80-110 respira- tions 21-22, dropped by crisis 5th day, no def- inite signs found in chest but roentgen ray examination one week after operation revealed diffuse mottled density throughout both chests, discharged well, 17th day
4	9996 S W Q. 39 February	(1) Chronic cystic mastitis (2) Tubo-ovarian abscess	(1) Well developed negroes, 123 pounds chronic cough and sputum history of precordial pain palpitation, lungs nega- tive tonsils and pharynx in- jected, systolic murmur, blood pressure 230/120 (2) See postoperative course	(1) Removal of left breast and axillary glands Supine position (2) Bilateral salpingo- ophorectomy includ- ing appendectomy, drainage Trendelenburg position	(1) Ether (Conolly) quiet throughout an- esthesia 1 hour 10 minutes operation, 1 hour 35 minutes (2) Ether (drop) 7 ounces anesthesia, 1 hour 10 minutes, op- eration, 1 hour quiet throughout	(1) Good recovery 6th day sudden rise in temper ature pulse and respirations 7th day, tempera- ture 101.4 F, pulse 140 respirations 48 septice- mic chart and elevation of temperature pulse and respirations until 27th day when abscess in pelvis was located and drained by operation (2) Poor recovery continued elevation of temper ature pulse and respirations pain in right chest and cough, examination of chest 3 days after second operation revealed dulness and râles at right base, coughing and pain, on 11th day a patch of bronchial breathing dulness and in- creased spoken voice appeared in left base rusty sputum, severe cough, fall of temperature, pulse and respirations by crisis 15th day dis- charged well but weak, to convalescent home 57 days after admission

101-2 V M G 2 24 March	Retraction of uterus	Rather frail appearing 100 pounds, no cardiac murmur, but history of dyspnea and precordial pain on exertion in the past, lungs normal blood pressure 92/60	Dilatation and curetage, ventral suspension of uterus, appendectomy, incidental omentectomy and Trendelenburg positions	Ether (drop) 7 ounces anesthesia, 1 hour 10 minutes operation, 1 hour 10 minutes well taken	Stormy recovery, rapid irregular pulse 140-180 respirations 20-25, temperature not above 100° F. 3d day, coarse crackling râles in left side and few in right, gradual rise in temperature to 102, dulness and râles at left base, much coughing 14th day, sepsis in wound, persistent dulness in left base with diminished breath sounds but no râles, same sounds in right axilla, gradual fall by lysis to normal in 17 to 20 days, discharged well, 25th day
101-3 V M G 2 26 April	Ovarian cyst	Fairly well developed and nourished 140 pounds (200 pounds 8 years previous), soft systolic murmur, lungs normal blood pressure 120/80	Removal of ovarian cyst, bilateral salpingectomy, ventral suspension of uterus, incidental appendectomy, Trendelenburg position	Ether (drop) 7 ounces anesthesia, 1 hour 25 minutes, operation 1 hour 25 minutes, quiet	Fair recovery 1st day after operation dulness and bronchial breathing right base, temperature 101° F, pulse 100, respirations 38, two days later pleurisy pains persisting for several days, consolidation spread throughout entire right back with râles but no dulness, left side, sputum negative for tuberculosis, full of diplococci, discharged against advice 15 days after operation dulness and râles present throughout right back with slight dulness and a few râles at left base
101-4 I F W 2 70 June	Plastric hernia strangulated	Dyspnea 10 years, hacking cough 14 years, rarely sputum blood pressure 100/70 heart systolic murmur slight enlargement lungs scattered fine râles posteriorly both sides weight 100 pounds	Repair Supine position	Gas oxygen 5 m a l anesthesia 1 hour 20 minutes, operation 1 hour 10 minutes, well taken irregular but not rapid pulse	Good recovery but within 24 hours rise in pulse, temperature and respiration temperature 101° F, pulse 110, respirations 40, breathing labored, pulse poor, enormously loud tracheal râles obscured pneumonic signs, which were present on both sides died 9th day after operation, no necropsy
101-5 I F R 2 11 June	Ventral hernia postoperative right	Rather delicate boy chlorea 4 years, subject to tonsillitis and colds 85 pounds heart and lungs clear, active coryza	Repair Supine position	Ether (drop) 5 ounces anesthesia 1 hour 5 minutes operation 1 hour quiet anesthesia	Good recovery, but steady rise in temperature, pulse and respirations, 3d day after operation temperature 103° F, pulse 120, respirations 35 râles at both bases with dulness beneath right scapula and diminished breath sounds, considerable cough returned to normal by lysis 12th day discharged well, 20th day
101-6 C V 2 27 July	Acute appendicitis with abscess	Well nourished but sick appearing intermittent precordial pain 9 months, heart and lungs normal, temperature 100.7° F, pulse 100 white blood cells 20,000 urine showed slight albumin few granular casts, few white blood cells	Appendectomy, drainage three days after onset Supine position	Ether (drop) 9 ounces anesthesia, 1 hour operation 55 minutes quiet anesthesia respirations rapid	Fowler's position, stormy recovery, in 48 hours temperature 102.2° F, pulse 170, respirations 60, definite consolidation at both bases and right superior lobe, tracheal râles, labored breathing, progressively worse, consolidation of entire right chest 5th day, died 8th day after operation necropsy, confluent bronchopneumonia, both lower lobes and portions of middle lobe
101-7 I S 2 1 July	Unrecovered left inguinal hernia left	Well developed and nourished 146 pounds heart negative lungs occasional squeaks operation deferred five days on account of coryza and bronchitis, blood pressure 120/80	Left repair Supine position	Gas oxygen 5 m a l anesthesia, 1 hour 5 minutes operation 55 minutes, smooth anesthesia	Temperature 101.4° F, pulse 120, respirations 40 at 4 p m, following day, examination of lungs revealed rather harsh breathing with coarse râles both apices dulness in left base at back bronchial breathing and bronchophony, cough, sputum diplococci not of type 1 or 2, temperature pulse and respirations dropped by lysis to normal 9th day after operation, discharged well 15th day

TABLE 5 — BRONCHOPNEUMONIA—Continued

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation, Position on Table	Anesthesia, Kind, Amount, Duration of Anesthesia	Postoperative Course, Pathology
11	11140 D McL ♂, 46 September	Hypertrophy of prostate	Well developed and nourished weight 180 pounds, heart and lungs negative, blood pressure 128/82	Suprapubic cystostomy with excision of median bar Trundelenburg position	Gas-o-x-y-gen 500 ml amount of ether anes-thesia, 1 hour 50 min-utes, operation 1 hour 35 minutes, well taken	Good recovery in 24 hours temperature 102.4 F pulse 120 respirations 36 slight cough, white blood cells 20,000, bronchovesicular breathing and increased whispered voice sounds at right base dulness moist râles at both bases, tem-perature, pulse and respirations dropped by lysis to normal 5th day after operation, lungs clear ing discharged well 18th day
12	11500 M M ♂, 60 December	Abscess of pros-tate abscess of epididymis bil-ateral, cystitis	Well developed and nourished heart and lungs negative blood pressure 100/80, weight 124 pounds (at one time 180) looks sick and septic tempera-ture blood pressure down to 110/60 at operation	Bilateral epididymot-omy evacuation of scrotal abscess, drain-ages, 25 days after admission Lithotomy position	Gas-o-x-y-gen 400 minutes anes-thesia operation 30 minutes quiet anes-thesia	Fair recovery slight cough diminished breath-sounds 2d day after operation temperature, pulse and respirations similar to before opera-tion until 5th day temperature 102.6 F, 12 hours later 101 F, pulse 130 respirations 35 dulness over right upper lobe diminished breath-sounds coarse crackling râles in both chests, died 8th day after operation, no necropsy
13	11505 F J O ♂, 31 November	Bilateral inguinal hernia	Well developed and nourished heart negative, lungs relative dulness and distant voice sounds in lower right back and axilla blood pressure 122/84, weight 157 pounds	Repair Supine position	Ether (drop) 8 ounces anes-thesia 1 hour 5 minutes operation 1 hour, coughed a little during induction otherwise smooth	Good recovery no vomiting elevation of tem-perature to 103 F on 2d day after operation, pulse 100 respirations 70 following day slight cough path of bronchial breathing, increased voice sounds few median râles at tip of left scapula temperature dropped by lysis to nor-mal 6th day after operation discharged well 18th day
14	11424 F McC ♂, 52 October	Adenocarcinoma of stomach	Well developed and nourished 137 pounds blood pressure 134/70 blowing systolic mur-mur, lungs negative history of palpitation and dyspnea teeth poor, severe pneumonia thirty years before	Resection (sleeve) Supine position	Proculn ether 1 ounce general anes-thesia 2 hours 10 minutes operation 3 hours well taken	Fair recovery no vomiting, following day dimin-ished breath sounds in right axilla 2d day, even ing, temperature 100 F pulse 112 respirations 32 cough râles over same area pain in right side with deep breath 6th day after operation dulness diminished breath and few crepitant râles in left axilla pain on coughing, tempera-ture dropped by lysis to normal 9th day after operation discharged improved 33d day
15	11386 F W ♂, 54 October	Trigeminal neuralgia (major, left)	Well developed and nourished 175 pounds blood pressure 112/78, heart and lungs nega-tive history of pneumonia fifteen years before and last year following operation for hernia and appendix	Abscission of left sensory root Supine position	Ether (concentrated) anes-thesia 1 hour 7d min-utes operation 1 hour 35 minutes	Good recovery, 2d day after operation tempera-ture 102.6 F pulse 120 respirations 20 cough, coarse râles over bronchi following day tem-perature 103.8 F, pulse 112, respirations 20 continued high temperature, pulse and respira-tion not much accelerated, many moist râles temperature dropped by lysis to normal 8th day discharged well 11th day
16	11150 G H S ♂, 70 September	Stricture of urethra, perure-thral abscess, urethral fistula (perineal)	Undernourished emaciated col-ored man 101 pounds, history of pleurisy, bilateral malaria, chronic sputum and cough night sweats shortness of breath, precordial pain teeth	(1) Perineal section drainage of perurethral abscess Lithotomy position (2) Suprapubic cystos-tomy, retrograde cath	(1) Proculn 1 cc (local) anes-thesia 1 hour 15 minutes (2) Proculn 5 cc 2 cc intraspinal operation 55 minutes	(1) Following morning, temperature 101.8 F pulse 100 respirations 23, in the afternoon normal fair reaction (2) Poor recovery irrational 1 p m temperature 102.6 F pulse 140 respirations 28, following day improved temperature normal, pulse 120, 3d

17	1121, 1117 of system her	Hypertrophy of prostate, cystitis, pyelonephrosis	Very poor lungs, slight gen- eral dullness, bronchial breath- ing left axilla, coarse râles both lungs, systolic murmur, blood pressure 120/85, cough and bloody sputum present	Externalization of urethra, drainage Supine lithotomy posi- tions		day after operation temperature 100.6 F, pulse 110 respirations 40 general condition very poor died 12th day after operation Necropsy chest chronic bronchitis with bronchiectatic cavities and abscesses, acute purulent bron- chitis, bronchopneumonia chronic emphysema with emphysematous bullae, emphysema of mediastinum chronic fibrous pleuritis
			Large heavy. Rather feeble man weight 177 pounds lungs negative heart sounds feeble with marked irregularity, his- tory of pleurisy, precordial pain, rare palpitation severe in influenza 1918 frequent dizziness blood pressure 140/80	(1) Suprapubic cystos- tomy, drainage Trendelenburg position (2) Suprapubic prosta- tectomy, drainage Trendelenburg position	(1) Procain 1% (local) operation, 50 minutes (2) Gas oxygen anes- thesia 45 minutes, op- eration 30 minutes quiet throughout	(1) Poor recovery vomiting, general condition gradually improved, cough occasionally, slight pulmonary emphysema (2) Good recovery, no vomiting, following day, afternoon, temperature 101.6 F, pulse 110 res- pirations 28, numerous coarse moist râles and sibilant râles rather diffuse, right and left bases mostly 3d and 4th days, temperature 103 F, pulse 120 respirations 30-36, many large coarse râles, no consolidation loose cough, tempera- ture, pulse and respirations on downward course temperature normal 7th day, bronchial râles profuse brownish sputum noted on 10th day died 13th day Necropsy chest, acute bronchitis, bronchopneumonia, chronic fibrous pleuritis
18	1118 of December	Hernia inguinal strangulated 78 hours	Fairly well developed under nourished, rather feeble, blood pressure 110/55 white blood cells 20,000 in bed three days with "a cold" before admis- sion, heart negative, lungs relative dullness few moist sounds at left base, breath sounds whistling, loud	Repair, reduction Supine position	Gas oxygen very little ether, anesthesia, 1 hour 35 minutes, opera- tion, 1 hour 15 min- utes, well taken, pulse 148 respirations 35	Poor recovery restless and irrational, getting out of bed following day, temperature 101.4 F, pulse 110, respirations 30, râles at left apex and later throughout lungs, died 3d day after oper- ation, no necropsy
19	1174 of December	Bilateral inguinal hernia	Well developed and nourished weight 155 pounds, heart and lungs negative, blood pressure 120/60, teeth very poor slight unproductive cough	Repair Supine position	Gas oxygen, few drops of ether twice, anesthe- sia, 1 hour 45 minutes operation, 1 hour 25 minutes well taken	Good recovery, no vomiting, 2d day after opera- tion temperature 102 F, pulse 180, respirations 24 patches of dullness and diffuse bronchitis, 4th day after operation, temperature normal, lungs clearing, discharged well, 18th day
20	1164 of December	Varix, internal saphenous sys- tem ulcer varicose	Fairly well developed and nour- ished, 150 pounds heart nega- tive blood pressure 117/80 lungs bronchovesicular breath sounds	Excision Supine position	Gas oxygen, anesthesia, 1 hour 45 minutes, op- eration, 1 hour 5 min- utes, very quiet	Good recovery, temperature 98 to 100 F, pulse and respirations normal, 9th day after operation, temperature 102.5 F, pulse 100 respirations 28, dullness at right back, "crackles", two days later temperature normal, discharged well, 23d day after operation
21	1064 of June	Carcinoma of rectum	Well developed and nourished Weight 175 pounds heart and lungs normal, blood pressure 150/100	First stage extirpation sigmoid divided above tumor, ends sutured colostomy just proxi- mal to upper end very marked Trendelen- burg position	Ether (drop) 12 ounces quiet general condition good throughout, pulse steady at 70, anesthe- sia 3 hours operation tion, 3 hours 5 minutes	Good immediate recovery, but within 24 hours rise of temperature to 102 F, pulse to 125, respira- tions to 35, patient lethargic, increasing cyano- sis, restless, abdomen negative, no cough, in 48 hours rapid rise in temperature, pulse and respirations, pulse irregular at 150, respirations 45 temperature 106 F, died Necropsy bron- chopneumonia, bilateral, carcinoma of rectum, postoperative wounds

Bronchopneumonia—Into this class fall the majority of all post-operative pulmonary complications. In our series, twenty-one cases, or 38.1 per cent, of the total complications were of this type, as opposed to 7.2 per cent of the lobar pneumonia group and 30.9 per cent of the next largest or bronchitis group. Not only is this the largest group but its mortality figure also exceeds the combined mortality of all the other complications. Thus, of our eleven deaths in the fifty-five cases with pulmonary complications, eight patients succumbed to bronchopneumonia. There is, however, much danger in a too close study of the figures alone, for the majority of old people at necropsy show some terminal or accompanying bronchopneumonic process, and we have tried not to include cases of patients who have died of a terminal bronchopneumonia in which we felt this was not the really important factor. As we have already stated, this is the typical postoperative pulmonary complication, and a close scrutiny of this class demonstrates most clearly the factors which are of importance in their etiology. The picture here presented is often definite and striking, and the etiologic factors become evident, whereas in the minor complications, such as pleurisy and bronchitis, although the cause may be, and probably is, the same, the indefiniteness and lack of intensity of the clinical picture make it difficult to determine the true underlying causes.

In the first place, we are impressed by the fact that the patients as a whole are poor risks. Of the twenty-one patients, eleven were over 50 years of age, and the ages in the fatal cases were 13, 27, 58, 60, 70, 74, 76 and 76. In addition, there was an existing pre-operative pathologic pulmonary condition or definite history of lung disability in ten instances (Cases 3, 4, 7, 8, 10, 13, 15, 16, 17 and 18). We would emphasize this, not that it is the chief etiologic factor in pulmonary complications, but because it is a factor that is frequently overlooked and to which little importance has in the past been attached. This is partly due to incomplete physical examinations, or to the system of operating in use in the majority of American clinics, whereby busy practitioners as attending surgeons to public hospitals do the bulk of the surgical work. It is really more the fault of the system than of the individual surgeon's lack of realization of the importance of such findings. There will always be emergency cases in which the local condition necessitates intervention irrespective of the lung findings, but what we would point out is that if this factor is understood, possibly local or gas-oxygen anesthesia, or a modification of the operative procedure may be sufficient to lessen the danger of a serious pulmonary complication. We believe that in this clinic this risk is quite well studied, we do adapt the anesthesia to the contingency, we do modify operation or if possible try to clear up the

lung condition before operation, and yet in this very class our morbidity and mortality figures are high. However, from experience we are convinced that without such precautions they would have been higher, and when one considers that of the eight patients that died, four were 70 years of age or more, the difficulties confronting our surgeons can be appreciated. Furthermore, a good many of the cases in the series included in Table 5 were so-called "septic" cases, four patients (Cases 11, 12, 16 and 17) were aged, with genito-urinary complications, cystitis, etc., from hypertrophied prostates or strictured urethra, two patients (Cases 1 and 9) had perforated appendices, and in Cases 2, 4, 7 and 18 there was infection. The importance of existing sepsis in the etiology of postoperative pulmonary complication lies in the liability of minute emboli from such foci to reach the lungs either by blood stream or lymphatic extension. Eighteen cases were laparotomies, three of these patients having epigastric incisions. The incidence of pulmonary complications with laparotomies and especially with epigastric incision is admitted in the literature as very high, and the explanation of easy extension of infection by blood vessels and lymphatics, the usual hypostasis in the lung bases from incising the abdominal wall, etc., are a sufficient explanation.

This brings us to the point which we constantly wish to emphasize, that the anesthetic cannot be blamed per se for postoperative lung complications. A study of the anesthetics in this group of cases shows eleven ethers, nine gas-oxygens and one procain. The patient operated on under local anesthesia (Case 16) was a bad risk, aged 70, septic and uremic. Immediate relief was indicated, local anesthesia and every precaution against a threatening pulmonary disability were used, but to no avail. The condition was almost terminal.

The patients operated on under gas-oxygen (Cases 7, 10, 11, 12, 14, 17, 18, 19 and 20) again reflect our preoperative study of the cases, and that we recognize the necessity of protecting certain types of patients from the very complications under discussion. In all these cases except Case 11, there were present factors leading us to consider the patients poor operative risks. Cases 7, 10, 17 and 18 showed a definite preexisting lung condition. In Case 12, there was a septic focus in a man, aged 60. In Case 14 there was adenopapilloma of the stomach in a man, aged 52, Case 19 was bilateral hernia in a man, aged 65, in Case 20 the patient aged 69, had varicose veins, in Case 11, the patient, aged 46, had hypertrophy of the prostate. The ages in all the latter cases were above the good risk age, Case 12 was distinctly septic. Case 14 a patient aged 52 in whom an epigastric incision was necessary for cancer cannot be considered a safe normal risk and in Cases 19 and 20 the age, the rather protracted

TABLE 6—BRONCHITIS

Case	Surg No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation Position on Table	Anesthesia, Kind Amount, Duration of Anesthesia Duration of Operation	Postoperative Course, Pathology
1	10033 E V Y Q, 29 February	Cholelithiasis	Well developed and moderately well nourished, 135 pounds average of pleurisy, palpable, history of pleurisy, poor, chronic tonsillitis, pneumonia, blood pressure 110/80, breath sounds and a wheeze, heart sounds and a harsh loud squeaking rales at right apex.	Cholecystectomy, laparoscopic, supine position	Ether (drop) 5½ ounces 1 hour 10 minutes, operation quiet throughout	Good recovery 2d day after operation, temperature 100.6 F, pulse 110, respirations 20, slight cough mucoid sputum, to 9th day, deep in cough to 100 F, both lungs pain on 17th numerous on left side, discharged well, 17th day after operation
2	10111 M E C Q, 45 March	Fibromyoma of uterus	Well developed and nourished, colored, weight 112 pounds history of dyspnea three times history pneumonia before, pre-tation, 15 months before, moderate cordial pain, lungs, apices few crackling rales heart murmur, diastolic blood pressure 150/110	Supravaginal hysterectomy, bilateral right oophorectomy, incidental hysterectomy, supine position	Ether (drop) 6 ounces 1 hour 15 minutes, operation quiet throughout	Stomachy F, pulse 110, respirations 40, extensive rales right back, gradual to 101 F until 12th day discharged well but weak 32d day
3	10201 S B Q, 45 March	Acute cholecystitis	Well developed and nourished, rather obese, 207 pounds, heart, systolic murmur, lungs a few rales, both bases, on inspiration	Cholecystectomy, drainage supine position	Ether (Connell) 55 min 1 hour 2 hours, operation anesthetic, subcutaneous	Good recovery 2d day after operation temperature 100 F, pulse 100 respirations 25, cough 4th day, tem perature 101 F 10th day, temperature 101.4 F, normal next day discharged well 20th day
4	10223 J F D Q, 19 April	Bilateral inguinal hernia	Well developed and nourished, 132 pounds, heart and lungs negative, 100/74	Repair supine position	Ether (drop) 6 ounces 1 hour 1 minute, operation well taken	Good recovery 2d day after operation 40 cough pulse 101 F, pulse 100 respirations 25, cough 4th day, tem perature 101 F 10th day, temperature 101.4 F, normal next day discharged well 20th day
5	10288 E F F Q, 55 April	Fibromyoma of uterus (malignant degeneration) general abdominal sarcomatosis	Well developed and nourished, 178 pounds, heart and lungs negative, blood pressure 160/98, white blood cells 22,000	Supravaginal hysterectomy, bilateral salpingectomy, appendectomy, oophorectomy, incidental hysterectomy, supine position	Ether (drop) 7 ounces 1 hour 15 minutes, operation 1 hour 20 minutes, throughout	Good recovery following day mucus in throat moist rales both chest 3d day, temperature 100.6 F, pulse 110 respirations 30 26 5th day, lungs clear pulse 100 respirations 20th day discharged improved

6	10-11 H F T April	Appendicitis subacute	Well developed and nourished 107 pounds (12½ pounds three months before) lungs nega- tive heart, systolic murmur (blowing) blood pressure 114/94 temperature 99.2 F white blood cells 12,000	Appendicectomy Supine position	Fther (drop) 5 ounces anesthesia operation quiet anesthesia	Good recovery at 8 p m, temperature 103 F, pulse 90 respirations 24, 12 hours later normal, 100 at 4 p m slight bronchitis noted, tem- perature remained normal after 3d day, dis- charged well 16th day
7	10-9 1 C May	Appendicitis, acute	Well developed, thin lungs neg- ative heart systolic murmur history of pneumonia, lobar 1014 teeth poor blood pres- sure 151/99	Appendicectomy, drain- age Supine position	Fther (drop) 8 ounces anesthesia, 50 minutes operation, 50 minutes unsatisfactory anes- thesia, pulse and respi- ration rapid subcy- anotic, much mucus	Good recovery, cough squeaks and grouns on expiration both backs, temperature pulse and respiration moderately elevated, normal 7th day, discharged well, 17th day
8	10-10 K W June	Pyosalpinx tubo-ovarian abscess	Well developed and nourished obese 113 pounds heart sys- tolic murmur lungs negative history of fracture of several ribs 11 years ago frequent pain in chest at site of above, blood pressure 110/70	Dilatation and curet- tage, bilateral salpin- gectomy left oophorec- tomy incidental ap- pendicectomy, drainage lithotomy and Tru- denburg positions	Fther (drop) 6 ounces anesthesia, 50 minutes operation 1 hour 25 minutes poor anesthe- sia cyanotic, vomited once	Good recovery, following day cough mucous spu- tum temperature 101 F (lower than before op- eration) respirations averaged 32 (24 preopera- tively), discharged well, 23d day
9	10-11 H H June	Inguinal hernia recurrent left strangulated	Well developed and nourished 120 pounds (emergency opera- tion history taken 9 days later) heart negative, blood pressure 106/68 lungs coarse ribs both bases, on inspira- tion frequent coryza	Repair Supine position	Gas oxygen, anesthesia 1 hour 15 minutes op- eration 1 hour, vom- ited food twice during induction, otherwise quiet	Good recovery 24 hours later, temperature 103 F pulse 120 respirations 30, cough examination of chest--acute bronchitis laryngitis 2d and 3d days, temperature 101 F, pulse 100 respirations 30 4th and 5th days, temperature 99.4 F 6th day 101 F, thereafter normal, discharged well 26th day
10	10-11 O S B August	Hydrocele left	Well developed and nourished 140 pounds heart and lungs negative, blood pressure 130/70 history of pneumonia 12 years before slight morn- ing cough teeth poor	Radical cure Supine position	Gas-oxygen, very little ether anesthesia 55 minutes, operation 45 minutes quiet through- out	Good recovery following day, temperature 101.4 F, pulse 108 respirations 30 infrequent cough slightly diminished breath sounds over angle of scapula, impaired resonance left base 3d day, temperature normal, discharged well, 8th day
11	11-18 N R October	Inguinal hernia right, recurrent	Small undernourished heart negative, blood pressure 100/60, lungs impairment to perfusion note at right apex few rales on left productive cough present teeth poor	Repair Supine position	Gas oxygen, a little ether anesthesia 1 hour 20 minutes oper- ation 1 hour 10 min- utes well taken	Good recovery, following day, temperature 101 F pulse 108, respirations 34 numerous coarse bubbling rales, both lungs back and apices productive cough temperature normal 7th day, discharged well 20th day
12	11-17 C M C October	Cholelithiasis	Well developed and nourished obese, heart and lungs nega- tive operation postponed 10 days before for bronchial cough	Cholecystectomy, chole- dochootomy drainage appendicectomy Supine position	Fther (drop) 15 ounces anesthesia, 2 hours 30 minutes operation 2 hours 25 minutes dilf- cult anesthesia, some cyanosis	Poor recovery, dyspnea, cyanotic, pulse and res- pirations rapid following day, temperature 100.8 F, pulse 160, respirations 60 cough, many rales both lungs same night pulse dropped to 120, respiration to 38, general improvement, discharged well, 28th day

TABLE 6—BRONCHITIS—Continued

Case	Surg No Name Sex Age, Date	Diagnosis	Preoperative Condition	Operation Position on Table	Anesthesia Kind Amount, Duration of Anesthesia Duration of Operation		Postoperative Course, Pathology
					Gas oxygen (mask), anesthesia hour 20 minutes operation 1 hour 20 minutes difficult anesthesia	ether 1 hour 10 minutes operation well taken	
13	11408 L. R. ♂ 39 November	Cholecystitis chronic	Well developed and nourished 170 pounds heart and lungs negative history of pleuritic pains, chest frequent yellow with considerable dirty blood sputum, teeth pressure 100/60	Cholecystectomy Supine position	ether 3 ounces anesthesia 1 hour operation well 5 minutes hour 10 minutes taken	ether 1 hour 15 minutes operation fairly well taken, some cough in.	stormy recovery much vomiting 24 hours later, difficulty in breathing slight cyanosis, diffuse bronchitis, cough sputum (profuse) tempera- ture 101.4 F., pulse 112, respiration 40 day after operation, discharged well, 24th day
14	11637 C. N. ♂, 63 December	Duodenal ulcer	Well developed and nourished 148 pounds, heart and lungs negative blood history of 80 teeth occasional cough with thick yellowish sputum	(gastric enterostomy) folding of pylorus Supine position	ether (drop) 3 ounces anesthesia 1 hour 15 minutes operation fairly well taken, some cough in.	ether 1 hour 15 minutes operation fairly well taken, some cough in.	Good recovery following day, temperature 98.8 F., pulse 104, respirations 35, dulness and crep- tant rales both chests temperature dropped 13th day respirations 24 6th day lungs clear opera- tion by lysis to normal 12th day, less, less, discharged improved, 32d day after operation slight cough and pain in chest following cough less, Good recovery, 2d day after operation slight cough and pain in chest following cough less, pulse 66 respirations 24 following cough less, most anorexia rales at right back cough 3d day discharged well, 17th day
15	11640 I. C. ♂, 49 December	Inguinal hernia left	Well developed and nourished 173 pounds heart and lungs negative blood pressure 124/80, teeth poor	Repair Supine position	Protein solution (local) operation hour 15 minutes	Protein solution (local) operation hour 15 minutes	Good recovery 100 F., moderate cough, considerable later moderate rales discharged well, 13th day cough and sputum discharged well, 13th day
16	11680 N. S. ♂ 57 December	Inguinal hernia left	Well developed and nourished 130 pounds (170 pounds a month ago), heart negative lungs, apex, pharynx injected right head cold and dry cough slight head cold and dry pressure for 24 hours blood pressure 125/75	Repair Supine position	Protein solution (local) operation hour 15 minutes	Protein solution (local) operation hour 15 minutes	stormy recovery for three days after operation afternoon temperature 101.5 F. pulse 120 respira- tions 25 temperature 100.5 F. in afternoon exam- nation four days after operation and com- plete four of lungs—few gurgling rales and com- parative dulness at right base discharged well, 17th day
17	11720 M. M. ♀ 46 December	Myoma of uterus	Well developed and nourished heart systolic murmur negative history of shortness of breath, dyspnea at 24 epi- leptopneumonia palpitation demic influenza anemia marked secondary blood marked slight catarth blood pressure 112/60	Supravaginal hysterec- tomy bilateral and salpingo-oophorectomy Freudenberg position	Protein solution (local) operation hour 15 minutes	Protein solution (local) operation hour 15 minutes	stormy recovery for three days after operation afternoon temperature 101.5 F. pulse 120 respira- tions 25 temperature 100.5 F. in afternoon exam- nation four of lungs—few gurgling rales and com- parative dulness at right base discharged well, 17th day

operation and the known incidence of embolism in such cases made them unusual. Case 11 alone appeared a good normal risk, and why the patient should have developed a complication is a little difficult to see. This patient showed an immediate onset of symptoms, the anesthetic was well taken, the recovery from it uncomplicated and the onset of the pathologic pulmonary condition remains unexplained. It is just such cases that bring most light to this subject for the general factors of anesthesia, pulmonary disease, etc., are lacking, and we believe that embolism alone gives such explanation.

In Cases 1, 2, 3, 4, 5, 6, 8, 9, 13, 15 and 21, ether anesthesia was used. In Cases 3, 4, 8, 13 and 15 there was either a definite lung disorder at the time of operation or a history of susceptibility to pulmonary trouble so definite that we should have taken warning. Cases 1 and 19 were both cases of ruptured appendix, the patients were very sick on admission, developed pneumonia almost immediately, and both died. The pneumonia revealed at necropsy was widespread. There was nothing unusual about the anesthesia, the amounts given were not large and the recovery in Case 1 was good and in Case 9 was stormy. The latter patient died in six days, and the former on the twenty-second day. In Case 1 there probably was a reinfection as the acute symptoms subsided after a week, only to recur with definite pulmonary signs four days before death. Cases 5 and 6 were rather frail appearing women subjected to pelvic operations in the Trendelenburg position. They each were given 7 ounces of ether, which was well taken, the operations lasting about one and one-fourth hours. In Case 6 there was a good recovery, in Case 5 a stormy recovery, the signs of pneumonia became evident between twenty-four and forty-eight hours but reached a maximum only on the third or fourth days. In Case 21, the patient was not considered a good risk, but had withstood cholecystectomy within a year without definite trouble so that the fatal pneumonia was a real calamity. The explanation, however, of the complication lies probably in the operation. For three hours, the patient was kept in marked Trendelenburg position. Otherwise, there was nothing unusual—7 ounces of ether, well taken, and good immediate recovery, but within twenty-four hours signs and symptoms of pneumonia appeared. Death occurred in forty-eight hours, pneumonia was certified at necropsy.

The study of this group of cases yields much of interest: first, that patients with an existing pathologic condition of the lung are susceptible to pneumonia if given ether; secondly, that intra-abdominal sepsis as ruptured appendixes, or the Trendelenburg position are also contributing factors in the incidence of postoperative pulmonary complications. We can find, however, no cases in our series with the exception of Case 11 spoken of above, in which the anesthetic can

in any way be held to be alone or even to the greater extent responsible for the postoperative pathologic condition of the lung. There are other and more definite reasons present, often and usually in conjunction. One of these is an already existing pulmonary disorder evidenced either in the physical examination or in the history, another is the presence of sepsis, and still another the generally recognized fact that in laparotomies and especially in cases in which the operation is in the epigastrium, the danger of extension of infection or the sending off of small emboli from the operative field is very easy through the blood vessels or lymphatic channels.

Bronchitis—In this class (Table 6), we had seventeen cases, 30.9 per cent, of the postoperative morbidity. The frequency of the condition is next to that of the pneumonias, but its absence of mortality makes its relative importance far less. However, a study of the factors in the causation of this complication brings out the same findings as previously stated under the pneumonias, and only tends to point the lessons we can learn more sharply. Of the seventeen cases, six patients were severely sick with prostration, great dyspnea, cyanosis and much mucus. Nine patients showed a preoperative lung disorder or gave a history of chronic pulmonary trouble. The average age was 40 years. All cases but one were laparotomies, and five were epigastric operations. Twelve patients were given ether, four gas-oxygen and one procain.

Definite criteria were taken in order to classify a case as bronchitis—râles, sputum and an accompanying general reaction giving a rise in pulse, temperature and respirations, and lasting over a sufficient number of days, at least three, in order that accessory and conflicting conditions might be ruled out. The fact that many of these patients were very ill with high pulse, temperature and respirations, râles, often pain, blood tinged sputum made the differential diagnosis from pneumonia difficult, but we accept as pneumonia only those cases with definite signs of consolidation. On the other hand, we may have missed a few very mild cases on which the postoperative notes left out certain findings thought unimportant.

The duration of the disorder varied from three days to two weeks. At the onset, there was often much cyanosis and excessive expectoration, often with the chest full of wet, noisy râles. The onset in all cases was within forty-eight hours, and subsidence occurred by lysis. The fact that all cases but one were laparotomies and in a high percentage of these there was an epigastric incision is in conformity with the universally accepted opinion that the incidence of postoperative pulmonary complications is higher in such cases, probably because of the free lymphatic connection between upper abdomen

TABLE 7 — PLFURIS

Case	Surg. No. Name Sex, Age, Date	Diagnosis	Preoperative Condition	Operation Position on Table	Anesthesia, Kind Amount, Duration of Anesthesia Duration of Operation	Postoperative Course, Pathology
1	1987 I C F, 45 January	Cholelithiasis	Well developed and nourished 175 pounds, heart and kidneys normal, blood pressure 18/105	Cholecystectomy appen- dectomy, drainage slightly reversed, Trend- elenburg position	Ether (drop) 7 ounces anesthesia, 1 hour 30 minutes, operation 1 hour 30 minutes, quiet throughout	Good recovery but some nausea and vomiting, seven days after operation pain on respira- tion right chest 9th day friction rub right axilla, relieved by strapping, no cough, lungs otherwise negative, slight postoperative rise in pulse, temperature, and respiration for three days, normal by time friction rub was made out, discharged well, 23d day after operation
2	1197 N H F, 40 December	Duodenal ulcer	Sallow, fairly well nourished 125 pounds, blood pressure 110/72, alcoholic long history of gastric trouble, teeth car- ious, no outstanding cardio- respiratory symptoms or signs	Posterior gastro-enter- ostomy, plication of pylorus supine position	Gas oxygen, procaïn anesthesia, 1 hour 40 minutes, operation, 1 hour 25 minutes	Good recovery, no rise in temperature, pulse or respiration, uneventful convalescence until 20 days after operation, complaint of occasional discomfort in right chest led to examination and finding of occasional friction rub and rela- tive dullness with rare rale at right base, dis- charged well, 27th day after operation

and root of lung The high occurrence among herniotomies, five cases in seventeen, is striking, and though difficult to explain, is a finding reported not infrequently in the literature, even with local anesthesia In our series, three of the five patients with hernia had a preexisting lung condition, of these, one was operated on under procain, the other two under gas-oxygen It may be that the high incidence of pulmonary complications with herniotomies is due to the fact that the pampiniform plexus is a very thin-walled structure, easily traumatized and, therefore, the seat of fine thrombi which later reach the lung, or, and we are afraid this is often the case, the patients with hernia are given to the junior members of the staff for operation and therefore subjected to less experienced operators

Although we have laid much stress on the presence of an already existing pathologic condition of the lung, we have also found a few patients with quite evident bronchitis who went through operation under gas-oxygen or procain without the slightest exacerbation in the pulmonary signs This is important, as it makes the factor of small emboli assume greater proportions

Pleurisy—Two patients developed pleurisy, both of a very mild type, one on the ninth day and one on the twentieth day (Table 7) Both patients had pain on respiration followed by a friction rub, and one, Case 2, developed signs of fluid at the base where the rub had been heard Both patients had epigastric incisions, but were considered good risks and did not have a preexisting lung condition It is our impression that these lesions are due to fine emboli, sterile, which stick in the capillaries close to the visceral pleura, the anesthetic playing no part Now and then, when such emboli come from a septic field, small peripheral abscesses form, break down, and we have a suppurative pleurisy if it is close to the pleura, or a lung abscess if it is in the substance of the lung

Lung Abscess—The two cases in this class (Table 8) are entirely divergent in type and etiology In Case 1 the patient recovered, a good risk with a subdiaphragmatic abscess following appendicectomy, later a sterile pleurisy by direct irritation and still later a small intrapulmonary abscess apparently embolic in origin which was cured spontaneously by evacuation via the bronchi and trachea The other case was fatal, and the condition almost terminal The case was a bad risk in an old patient with chronic urinary stasis and many operations The risk was recognized and gas-oxygen or procain used, but in spite of this, the foci in the lungs steadily became more outspoken and either through embolism or bronchial stasis, lung tissue itself became involved and an abscess in addition to a diffuse severe bronchitic condition was present at necropsy

TABLE 8—LUNG ABSCESS

Postoperative Course, Pathology				
Case	Surg No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation, Position on Table
1	9932 H B S d, 31 February	(1) Appendicitis, acute (2) Subphrenic abscess, right	(1) Well developed and nour- ished, heart and lungs nega- tive, white blood cells 16,000 (2) White blood cells 18,000 (tenderness right costal border)	Appendicectomy, drain age Supine position (2) Drainage Supine position
				Anesthesia Kind Amount Duration of Anesthesia Duration of Operation Ether (drop) 10 ounces anesthesia, 55 minutes, operation, 50 minutes (2) Procaïn (local) op- eration, 30 minutes
				Good recovery, no vomiting, 11 days postopera- tive thoracentesis, 300 c.c straw colored fluid, culture sterile, temperature and pulse steadily rose second operation 14th day. Good recov- ery, but little change in temperature, dulness right chest persisted, three days following sec- ond operation, thoracentesis repeated with re- moval of straw colored fluid, roentgen-ray examination unsatisfactory, medical consulta- tion—dulness at left base, voice sounds and dis- breath sounds diminished except small area at angle of scapula where bronchophony and dis- tant bronchial breathing heard anteriorly— friction rub below the right nipple, diagnosis— lung abscess plus some fluid, 20th day after first operation patient coughed up large amount of foul, purulent material following which tempera- ture, pulse and respiration came to normal within 24 hours and convalescence thereafter was uneventful, discharged well, 32d day
2	11534 H L d November	Stricture of urethra	Well developed and nourished (rare colds), lungs, rare râles left back near angle of scap- ula and right base, 7 years of urinary difficulty, curious ne- crotic teeth, pulse 100	(1) External urethrot- omy Lithotomy position (2) Suprapubic cystoto- my, 2 drains Trendelenburg position (3) Placement catheter to bladder through per- ineal wound Lithotomy position
				(1) Gas oxygen anesthe- sia, 1 hour 20 minutes operation, 1 hour 10 minutes, quiet anes- thesia (2) Gas-oxygen - ether, anesthesia, 1 hour, op- eration 40 minutes well taken (3) Procaïn (local), op- eration, 10 minutes
				(1) Fair recovery, rise in temperature, pulse and respiration not marked, localized pain, second operation 48 hours later (2) Fair recovery, became weaker, diffuse râles in both chests, some dulness left chest continued to 3d day, gradually better but continued to cough considerable purulent material, 14th days friction rub right base, quite suddenly 29 days after second operation developed septic tuber- culosis with elevation of temperature, pulse and respiration which continued to death 21 days later with onset of this period bronchial breathing and râles appeared in entire left chest with cough, gradually the right lung also be- came involved in the same pneumonic process, sputum became purulent but not malodorous death without marked change Necropsy pul- monary abscess right, bronchopneumonia, local- ized emphysema, right, arteriosclerosis, etc

TABLE 9 —EMPYEMA

Case	Surg No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation, Position on Table	Anesthesia Kind Amount, Duration of Anesthesia Duration of Operation	Postoperative Course, Pathology
✓ 1	10076 O B ♂, 35 August	Chondroma chest wall involving 2d, 3d and 4th ribs anteriorly, the size of an ostrich egg	Vigorous, well developed and nourished, 148 pounds, recent ly slight bronchitis heart and lungs negative except for com- pression signs, right chest, below tumor blood pressure 140/90 trachea aorta and heart displaced to left	(1) Excision of tumor including 1st, 2d and 3d ribs (portions) ante- riorly (2) Thoracostomy 11 days later (trocar catheter method only local anesthesia) for suppurative pleurisy	Ether (Connell), intra- tracheal attempted but discarded, anesthesia 4 hours 50 minutes op- eration, 4 hours 15 min- utes, perfectly smooth	Slow but satisfactory recovery from prolonged operation steadily daily rise in temperature pulse and respirations 3d day, temperature 105 F, pulse 120, respirations 40, thoracentesis at this time serous fluid apparently uninfected, white blood cells 6,000 condition slowly im- proved temperature and pulse fell but breath- ing continued labored with expiratory grunt—40 white blood cells 15,000 5th day, evidence of harsh breath sounds and fine crackles at right axilla coughing in paroxysms on 12th day evidence of consolidation beneath the scapula posteriorly made out bronchial breathing and râles white blood cells 22,000 coughing in creases when lying on right side and a foul expectoration brought up condition critical 13th day cyanotic tracheal râles sputum and breath- odor of lung abscess thoracentesis yielded purulent fluid, (2) under procain catheter in- serted into chest through cannula seropurulent fluid containing streptococci prompt improve- ment irrigation of chest, irritating fluid tasted (evidence of bronchial fistula, presumably small lung abscess had ruptured into pleural cavity) steady, slow improvement catheter connected with tube constantly immersed in saline, saline irrigation daily cough cleared gradually, 40th day roentgen ray (some cloudiness at right base and small area of pneumothorax about opening) 43d day up in chair, 45th day off constant drainage rapid improvement dis- charged well 46th day right lung clear both to physical signs auscultation and roentgen ray, 10 pounds only below weight on admission

Empyema—The single case in this class (Table 9) was exceptional and followed direct operation involving the pleura itself. However, a close study would seem to show that probably the infection began as an intrapulmonary lesion. The patient was an excellent risk, but was subjected to a prolonged and dangerous operation. Intratracheal anesthesia (ether) was attempted but discarded, and the mechanical irritation at this stage may be blamed for the subsequent trouble. Immediately following operation, the temperature, pulse and respirations rose characteristic of pneumonia, and the signs of consolidation became evident a few days later in the right axilla. Aspiration yielded serous fluid on the third day after operation. The condition was stationary for a week, then about the twelfth day there was a rather sudden change for the worse, with cyanosis and marked pulmonary edema. The sputum became progressively more and more foul, almost suggesting gangrene of the lung. Drainage was established with a catheter, and there was rapid improvement, but irrigations with a surgical solution of chlorinated soda (Dakin's solution) revealed the presence of a bronchial fistula. The drainage was removed on the forty-sixth day, when the chest was almost entirely free of pathologic signs. The patient was discharged well on the sixtieth day.

Embolism—In this class there were three cases and two fatalities. The fatalities were typical of this complication. Operations were on the kidney and prostate. Large thrombi must have formed in the great veins and slid off on the third or fourth day. There were no premonitory signs in Case 1, but in Case 3 the fatal onset was preceded for twelve hours by a local pain at the site of operation. The lesions were certified at necropsy. In Case 2 we anticipated an even more serious result, as operation had revealed large thrombi in old varicose veins. Apparently, a very small embolus was loosened on the twenty-third day followed by chest pain, chill, but no other pulmonary signs or symptoms. In our experience, the last type of case is always to be considered dangerous from the fear of this very complication.

In the group of pulmonary embolism (Table 10) are included cases in which a sudden pulmonary upset occurs owing to circulating thrombi wedging in large pulmonary vessels. As a rule, such cases are fatal and, although minute thrombi may and probably do occur in a majority of all postoperative pulmonary complications of whatever group, they are not classified under this heading but under the clinical condition they cause. The clinical picture of pulmonary embolism is too well known to need discussion.

Pulmonary Complications in Tuberculous Patients—We believe that a study of this group of cases is of the greatest importance because careful selection of cases may prevent disaster and when complications

TABLE 10—PULMONARY EMBOLISM

Case	Surg No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation Position on Table	Anesthesia, Kind, Amount, Duration of Anesthesia Duration of Operation	Postoperative Course, Pathology
1	9738 W. O. S ♂, 60 January	Pyonephrosis	Well developed and nourished heart and lungs normal blood pressure 138/83	Left nephrectomy, drainage Tumbar position	Gas oxygen (very little ether) anesthesia 1 hour 40 minutes oper- ation, 1 hour 20 min- utes, quiet anesthesia	Good recovery no appreciable elevation of tem- perature pulse or respiration, 4th day after operation, sudden convulsive seizure, uncon- sciousness, jerky respirations poor color, im- perceptible pulse, momentary consciousness vomiting imperceptible pulse great dyspnea, death Necropsy cardiac and pulmonary em- bolism, pyelitis, etc
2	11075 J. A. M ♀, 34 Septem- ber	Thrombo- phlebitis, left, internal saphenous system	Well developed and nourished 150 pounds, heart and lungs normal, blood pressure 110/60 severe sore throat and sub maxillary glands, left, 2 weeks before, temperature 105° F pulse 130, respirations 40 on admission	Incision and drainage (in bed)	Gas oxygen anesthesia 15 minutes operation 10 minutes, well taken	Uneventful course following operation T remain- ed septic but general condition satisfactory suddenly 23 days after operation attacked with severe pain in the left lower chest anteriorly with chill immediate rise of temperature pulse and respiration and continued elevation of all for a period of three days from which time patient made a rapid and steady return to nor- mal at time of attack no change in chest symptoms no cough discharged well, 32d day after operation
3	10240 H. N. O ♂, 65 April	Obstructing prostate (median bar)	Well developed and nourished heart and lungs negative, blood pressure 101/64	Suprapubic partial pros- tatectomy, drainage Trendelenburg position	Gas oxygen (very little ether) anesthesia 45 minutes operation 35 minutes well taken	Good recovery convalescence uneventful until 3d day when without warning several fleeting at- tacks of pain in pelvis occurred, increasing in severity following last and most severe attack of pain patient unconscious and died in a few minutes Necropsy pulmonary embolism, thrombosis of veins prostatic plexus, early cancer in bile passages, etc

do ensue it may mean sanatoriums for life, whereas otherwise the lung disease might have remained quiescent for years. A good many patients with fairly quiescent pulmonary tuberculosis will appear yearly in any large clinic, and the cases we present are probably representative of most clinics in large cities. In the five cases summarized (Table 11), all the patients had either pulmonary signs or a history leading one to suspect tuberculosis. In Cases 1 and 2, the patients became progressively worse with marked pulmonary symptoms and were finally transferred to sanatoriums for further care. The other three patients after acute flare-ups recovered and were discharged with apparently inactive lesions and in about the same condition as on admission. In addition to these cases were found three other cases of pulmonary tuberculosis among those patients operated on in the year under discussion, all of whom showed no appreciable change and therefore are not counted as cases of postoperative pulmonary complications. The two patients that became worse were given ether, and it is fair to say that tuberculosis was absolutely unsuspected. In the other patient having ether (Case 4), we did not take much stock in his story as he was a particularly well developed man—a great mistake on our part. The other two patients and also the three mentioned as being unchanged by operation received gas-oxygen or procain, and it is our opinion that in this very field the added irritation of ether is a mistake. However, even here we must not be too sure of the part the anesthetic plays, for in the light of such a general study, the facts that in all cases sepsis was present and that the abdomen was the field of operation assume greater proportions.

Pulmonary Complications—Mistaken Diagnoses—Among the cases of the year reviewed are found two patients, aged 13 and 45, with pneumonia operated on for appendicitis, in whom normal appendixes were found. Gas-oxygen anesthesia was used in both cases and recovery occurred by lysis in one case and crisis in the other. The definite signs and symptoms of lobar pneumonia, right side, were evident the day following operation. There need be no discussion of this, as it is simply an example of mistaken diagnosis, and we include the cases only to add weight to our underlying plea that the careful examination of lungs is one of the most important steps previous to any operation.

Empyema and Lung Abscess—In a study such as this, we believe that patients suffering from and operated on for either empyema or lung abscess are not to be considered, since an increase in the amount of the lung disability is almost sure to occur. However, it is true that were such cases badly handled, operation performed under full ether anesthesia, etc., just criticism should fall on those responsible

TABLE 11—EXACERBATION OF TUBERCULOSIS

Case	Surg. No., Name, Sex, Age, Date	Diagnosis	Preoperative Condition	Operation Position on Table	Anesthesia, Kind Amount, Duration of Anesthesia Duration of Operation	Postoperative Course, Pathology
1	9958 J. T. ♂, 20 February	Appendicitis, subacute	Fairly well developed and nourished, 115 pounds, heart and lungs negative, blood pressure 112/60, history of vomiting a tumbler full of blood about every three months	Appendectomy (no drainage) Supine position	Father (drop) 4 ounces anesthesia, 10 minutes operation 40 minutes quiet anesthesia	Good recovery. 2d day pain in chest, right, examination negative but 3d day find rates, right base, steady rise in pulse, temperature and respirations, 5th day back signs later of fluid breathing right lower back signs right lower back breathing ray 21st day, dulness above this 33d roentgen ray 21st day, mottling above temperature, with fluid here and in sputum, temperature, day, tuberculous remains elevated transferred cal consultation acute tuberculous 31st day to tuberculous sanitarium
2	10550 F. H. G. ♂, 14 May	Tuberculous peritonitis (admission diagnosis acute appendicitis)	Well developed and nourished 130 pounds negative back not examined white blood cells 14,000	Exploratory laparotomy Supine position Generalized peritonitis found (drainage)	1 ether (drop) 6 ounces anesthesia 10 minutes operation 40 minutes quiet, respirations and pulse rapid	Good recovery but running typical hectic chart throughout right and vocal fremitus white blood cells 15,000 diarrhoea discharged 30th day, loss of very active signs as in Case 1 to tuberculous sanitarium
3	11478 B. S. ♂, 54 November	Ulcer of stomach (hour glass contraction)	Emaciated 81 pounds, ulcer and admission diagnosis ulcer and ? of pulmonary tuberculosis refused operation one for 2 years cough, sputum, blood night sweats normal blood pressure 142/90 lungs with foul heart right lung with pressure of dulness right no hour of dulness breathing no hour bronchial breathing no hour roentgen ray of stomach ulcer lesser glass contraction ulcer lesser curvature	Cauterization of ulcer posterior gastroenterostomy Supine position	Gas oxygen (no ether) anesthesia, 2 hours 1 minutes operation 15 minutes quiet throughout	Good recovery slow rise in pulse temperature and respirations not marked, 5th day tubular breathing left base with rates slight hemoptysis white blood cells 17,000 disappeared in dulness and tubular breathing sputum consals three days but for tuberculous front to four lobes which also disappeared 30th day
4	11109 H. W. ♂, 40 August	Appendicitis, acute	Well developed and nourished 156 pounds white blood cells negative, temperature 101.2 F 17,000 history of splitting up blood for a week 4 years before	Appendectomy drain	Father (drop) ? anesthesia 15 minutes operation 25 minutes smooth anesthesia	Good recovery slight rise of temperature pulse and respirations 12th day after operation small pain in right back on deep inspiration small area of amount of blood stained base posteriorly with dulness of diminished breath base diminished question of diminished right base occasional rates, dulness, vocal fremitus with occasional roentgen ray dulness, vocal fremitus obtained roentgen negative thoracotomy un-satisfactory signs of consolidation examination un-satisfactory with rates, general condition for tuberculous with few rates, roentgen ray for right base with 25th day roentgen ray entirely un-satisfactory base and right apex mottled areas right base and condition excellent marked 28th day general per-sistens but physical signs in chest persistens
5	11554 F. L. O. ♂, 33 November	No diagnosis (admission diagnosis acute appendicitis)	Well developed and nourished 130 pounds negative white blood cells 15,000, hacking cough (lit tie sputum) for 9 years, discharge nasopharyngeal pharynx red blood tonsils and teeth roentgen ray injected 110/60 pressure 110/60 of tuberculous very active signs	Exploratory laparotomy Only incidental appendectomy Supine position	Gas oxygen (no ether) anesthesia 1 hour 10 minutes operation 20 minutes well taken	Good recovery slight gradual rise of temperature to 101 F on the 5th day 5th day dulness right upper chest front and back, pro-nal lung clear ink, sputum no tuberculous found discharged in good condition 21th day after operation

There were thirteen patients with empyema and two patients with lung abscess submitted to operation in the series studied. Three patients were given gas-oxygen anesthesia, and all the others were operated on under procain. The two patients with lung abscess died, all of the patients with empyema recovered. There was in addition one patient with a mediastinal abscess following influenza with bronchopneumonia who, following incision and drainage under gas-oxygen, did well and was discharged in good condition.

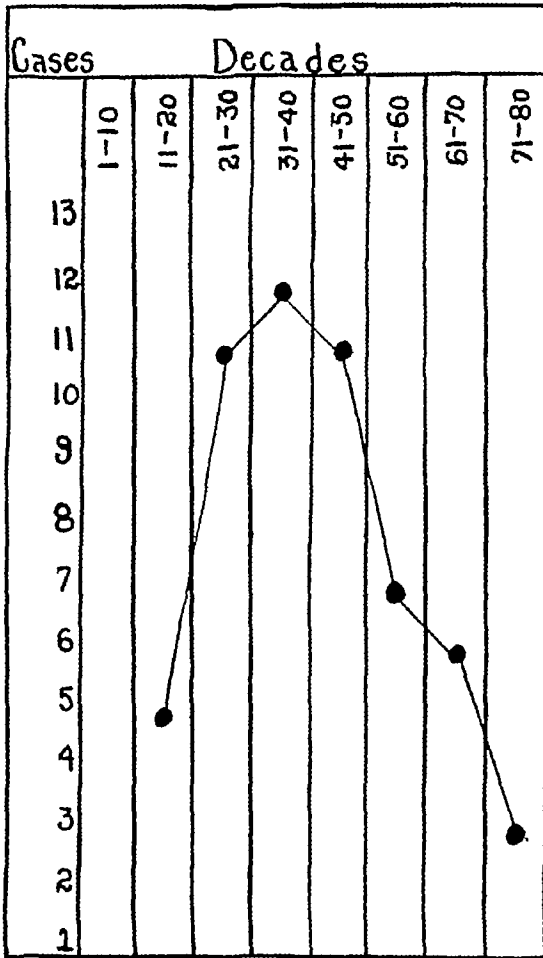


Chart 1—Incidence of postoperative pulmonary complications by decades

GENERAL DISCUSSION OF THE MATERIAL

Chart 1 shows the incidence of postoperative pulmonary complications by decades, Chart 2 the seasonal variation, and Table 12 the methods of anesthetization in this report in relation to the morbidity. Sixteen patients included in Chart 1 were more than 50 years of age, and twenty-seven were more than 40, bringing 50 per cent of the cases into the later years of life and the proportion of post-

operative morbidity to a very high point among the aged and infirm. This is, however, no higher than figures by Osler and McCrae¹⁰ for such cases in simple infectious pneumonia.

Chart 2 is not striking, but it does show an increased incidence in the colder months, which is in conformity with the findings in our previous investigation and with those of Whipple,³ Armstrong,⁸ Balfour⁵⁰ and other investigators.

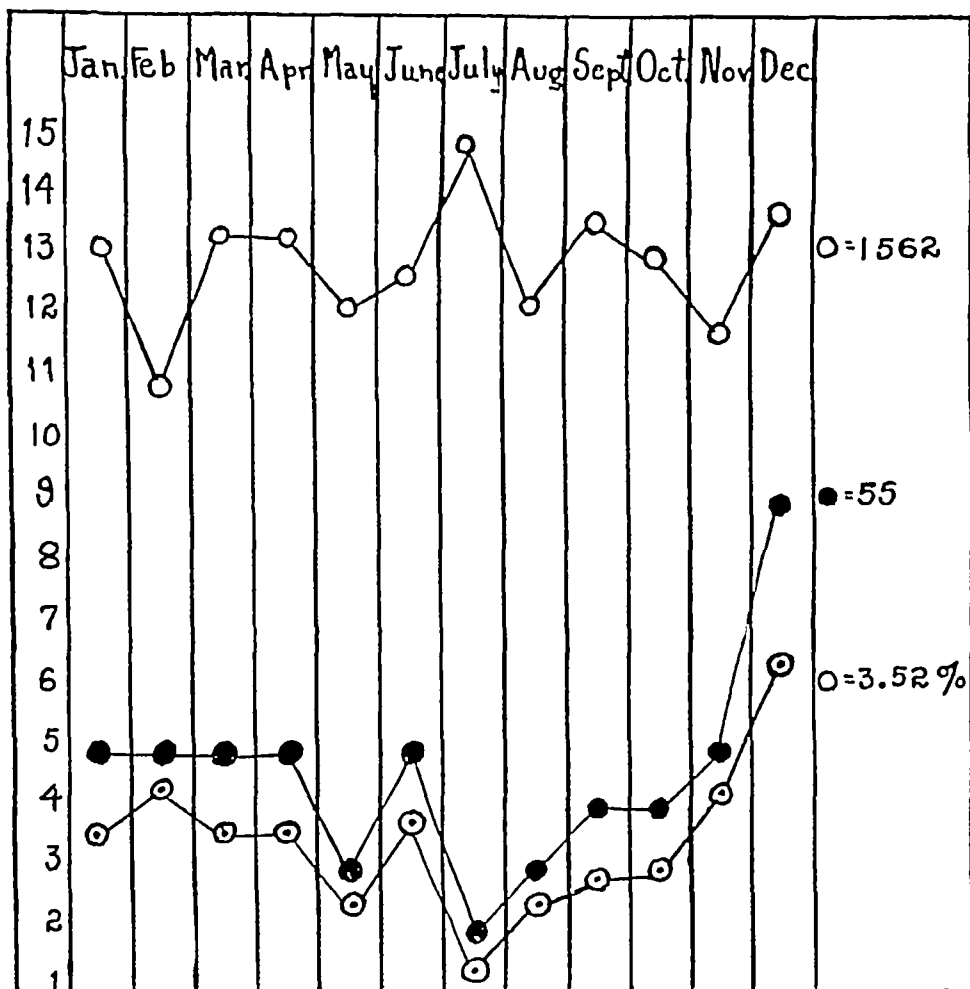


Chart 2—Seasonal variations in postoperative pulmonary complications: open circle, number of operations per month, the number at the side should be multiplied by 10; solid circle, number of pulmonary complications per month; circle and dot, percentage of pulmonary complications per month.

Table 12 gives the number of complications occurring with the different anesthetics. Of the total 1,562 operations, 943 were performed under ether, 495 under gas-oxygen, 117 under procain, and two under chloroform and five with spinal anesthesia. This gives a

⁵⁰ Balfour. Collected Papers Mayo Clinic, Philadelphia, W. B. Saunders Company, 1913, p. 743.

morbidity percentage of 3.39 for ether, 4.24 for gas-oxygen and 1.63 for procain. But we must know that the "bad risk" patients were given gas-oxygen, otherwise the higher figure for this group might be translated wrongly. However, these figures do as a whole support our belief that the rôle of the anesthetic is usually a minor factor. Otherwise, the proportion of complications under ether, which is certainly more irritant, would be higher. It is true that the incidence under procain is low, but, again, one must remember that operations under local anesthesia are performed gently and it is used only rarely in septic cases.

TABLE 12—POSTOPERATIVE COMPLICATIONS FOLLOWING VARIOUS ANESTHETICS

Complication	Anesthetics				
	Ether	Gas Oxygen Ether	Gas Oxygen	Procain	Totals
Lobar pneumonia	8		1		4
Bronchopneumonia	11		9	1	21
Bronchitis	11	1	4	1	17
Pleurisy	1		1		2
Empyema	1				1
Pulmonary embolus			3		3
Lung abscess	1	1			2
Exacerbation of tuberculosis	3		2		5
Totals	31	2	20	2	55

A discussion of the various methods of giving anesthesia we hardly think necessary, since such performances are now well standardized, and especially since we believe that the evidence is overwhelmingly in favor of other factors in the etiology. In this clinic, ether is given either by the open drop method using a Ferguson mask, or by the Connell ether machine and an intranasal tube. For gas-oxygen we use the Connell gas machine, using in addition to the basic gases, when necessary for relaxation or other causes, a few drops of ether. Procain, 1 per cent, is used for local anesthesia. Careful anesthesia charts are kept with records of pulse and respiratory rate every ten minutes or more frequently if necessary, blood pressure readings are kept during more serious operations and the time of beginning anesthesia, beginning of operation, closing of anesthesia and end of operation are carefully recorded. The anesthetists, in addition, record the amount of anesthesia, general reaction of the patient, and any further data which they may think of importance or use. Trained nurse anesthetists are employed in addition to the house officers to whom they give instruction, and the staff of this hospital believes that this is one of the most satisfactory elements in our operating room work. As a result of this study we have suggested that our anesthesia records be made more complete by recording on the back of the chart the bed-

side notes for the first twenty-four hours after operation. Patients in this hospital recover in special rooms under observation on the operating room floor, and every precaution is taken during and after operation to protect the patients from chilling and exposure. The only loophole of importance rests beyond such operative or postoperative care. It resides in the judgment of the surgeon as to when and how to operate, or rather when not to operate. There can be no shifting of this responsibility to the methods of anesthesia or to the after-care.

TABLE 13—PULMONARY COMPLICATIONS

Complications	Number of Cases	Morbidity per Cent	Number of Deaths	Mortality per Cent of Morbidity	Approximate Morbidity per 100 Cases	Approximate Mortality per 100 Cases
Lobar pneumonia	4	0.25	0	0.0	1 in 391	0
Bronchopneumonia	21	1.34	8	38.0	1 in 74	1 in 19.5
Bronchitis	17	1.08	0	0.0	1 in 92	0
Pleurisy	2	0.12	0	0.0	1 in 781	0
Empyema	1	0.06	0	0.0	1 in 1792	0
Pulmonary embolism	3	0.19	2	66.6	1 in 521	1 in 781
Lung abscess	2	0.12	1	50.0	1 in 781	1 in 1792
Exacerbation of tuberculosis	5	0.32	0	0.0	1 in 312	0
Totals	55	3.52	11	20.0	1 in 284	1 in 142

Morbidity of pneumonia group to total operations, 1.6

Mortality of pneumonia to total operations 0.51

Table 13 depicts the seriousness of this problem and indicates in which group we shall find the fatalities. All investigations have revealed a very high incidence of pneumonia and, as we have discussed on an earlier page, the literature on postoperative pneumonia is by no means meager. Because this group carries such a serious result, we, too, have spent most time in its study. The opinions as to its etiology are often divergent, but may be roughly divided into the embolic and irritative groups with the general factors of age, seasonal incidence, preexisting pulmonary disorder and sepsis as contributing factors. If these lesions were purely irritative, unquestionably the anesthetic must be at fault and improvements in the methods of anesthesia with absence of vomiting, decreased salivation and inhalation of mucus and the open drop method would have shown a marked reduction in this complication. Also, patients with a preexisting lung lesion would be almost certain to have a pulmonary complication. This is not the case. In spite of the writings of Magaw⁴⁷ and Henderson,⁴⁸ we submit that even with anesthesia in skilled hands, pneumonia claims a high morbidity. In 1916, in this hospital, the pulmonary complications reached 4.37 per cent, and they still remain at 3.52 per cent in spite of the fact that the majority of all anesthetics are administered by highly trained people. Besides, there is much evidence on the other side. Primarily, pulmonary complications are

not infrequent under local anesthesia, they are also common under gas-oxygen anesthesia, they occur even when the anesthesia is administered by a skilled and highly trained anesthetist. Also they seem to be present in a more definite proportion to certain other factors. The chief of these is sepsis. The fact that all our fatalities occurred in patients either operated on for inflammatory lesions primarily, or in whom sepsis could have occurred as in intestinal operations, is strong evidence. Moreover, the reports of Ranzi,⁹ Kelling,¹⁸ Bibergeil¹² and Burnham²⁸ emphasize the importance of sepsis. We submit that the danger of sepsis lies in embolism, and that embolism is the chief source of pulmonary complications except in those patients already presenting definite pulmonary lesions. In using the term embolism, we include

TABLE 14—RELATION OF OCCURRENCE OF PULMONARY COMPLICATIONS TO MOBILITY OF THE OPERATIVE FIELD

Operative Field	Complications								Totals
	Lobar Pneu monia	Bron cho pneu monia	Bron chitis	P'eu risy	Empy ema	Pul mo nary Em bolism	Lung Ab scess	Exacer bation of Tuber culosis	
Cranium		1							1
Thorax					1				1
Kidney	1					1			2
Upper abdomen	1	3	5	2				1	12
Lower abdomen									
1 General		4			2		1	4	11
2 Inguinal hernia	1	5	5						11
Pelvis	1	3	4						8
Prostate (suprapubic)		2				1			3
Perineum		2					1		3
Scrotum			1						1
Lower extremity (varicose veins)		1				1			2
Totals	4	21	15	2	3	3	2	5	55

transmission by lymphatic channels as well as by the circulatory system. In patients with a preexisting pulmonary disorder, and they are sometimes overlooked even in the best clinics, a local increase in the already present condition by direct extension may be the etiologic source. If we accept the findings of Whipple³ and Stillman²⁰ as to pneumococcus carriers, the mechanism is easy to understand. In our first study in 1916,² we, too, took this attitude and felt that although the anesthetic was not the chief factor the etiology lay in its irritant action on an already existing, though possibly quiescent, lung disorder. A more careful study such as this, possibly because of more complete and accurate data, has shown us that this alone does not explain the situation. Too many patients develop a complication without any preexisting lung disorder, either under perfect anesthesia conditions or under local anesthesia. As evidence to support our contention in regard to

embolism, we have the fact that fatal pulmonary embolism does occur and is easily recognized pathologically. Moreover, it may occur early. In this study, the two fatal cases occurred on the third and fourth days. Further evidence as to the part sepsis plays in this lesion is not necessary (Kelly,⁵¹ Ranzi,⁹ and McCann⁵²). The setting free of such emboli depends (1) on sepsis, and (2) on the mobility of the part. The latter factor is recognized by other observers, and further proof is shown by the higher incidence of pulmonary complications in parts of the body which cannot be kept at rest. Table 14 shows strikingly the relation of the mobility of the part to the occurrence of pulmonary complications.

Thus, approximately 2 per cent. of all patients operated on develop a pulmonary complication, when the field is confined to the abdomen; the incidence rises to 4 per cent., while in 8 per cent. of epigastric operations some one of the lung complications develops. Moreover, in cranial operations such lesions are rare. Why? Because in the last class there is perfect splinting of the tissues from the underlying bone, whereas in the other groups mentioned mobility of the part rises with the increasing incidence. In the epigastrium each breath pulls on the wound, and no matter how gentle the surgeon, or how accurate his approximation, small thrombi will in time be loosened and showered into the lung. If sepsis is present, and this occurs at once because of manipulation, a pulmonary complication is assured. Moreover, in these very cases we have direct lymph drainage and also hypostasis, the latter increased (1) by the dressings, and (2) by the effort of the body itself to splint the part. We do not think the fact that the complications as a rule appear shortly after the operation is evidence against embolism, and for the irritant effect of the anesthetic. In this study, forty-two patients (76.4 per cent.) showed signs and symptoms within forty-eight hours. Certainly, the manipulation on the table would be greater than any subsequent mobility, and doubtless many fine thrombi are set free at this time. The fact that the majority of such patients were operated on for septic lesions makes these emboli only the more dangerous, and if a preexisting lung lesion is present in addition, the danger of an ensuing complication is increased. A study of the operators throws some light on these facts. The men considered as gentle slow operators have a proportionately lower morbidity, which we consider to be an added reason for the embolic theory. These men, though subjecting their patients to a longer operation, cause less trauma and therefore cause less thrombosis.

51 Kelly. *Brit. M. J.* 2: 17, 1912.

52 McCann, F. J. *Brit. M. J.* 1: 277 (March 9) 1918.

Having established in our own minds that embolism is the chief factor at work, we must confess that there are often other factors of varying importance. Thus, the part which a preëxisting lung lesion plays is often considerable. In twenty-two of the fifty-five cases, in addition to the five tuberculosis cases there was given by history or physical signs, evidence of a preoperative pulmonary disease. At the time of operation, these findings were not seriously considered, but in a careful postoperative study their importance is indicated. It was this finding which in the first study by one of us in 1916 in collaboration with Morton,² made us feel that the eradication of this difficulty lay in a more careful preoperative study of the lungs. Whipple³ reported a preëxisting lung lesion in twenty-five out of the ninety-seven complications in his series. Others may not have been noticed. In the light of the present study the importance of this factor cannot be overestimated, since if we have an already subacute lung lesion and shower into it fine emboli, even if they are not septic, they will cause sufficient circulatory and pressure disturbance to cause the existing latent process to flare up. It is certainly the latter group in which the anesthetic might have considerable effect, and if the patient is already a pneumococcus carrier, the conditions for infection are fulfilled. Here such a thing as an irritative pneumonia or bronchitis might result. If it did, it would presumably be a local affair, and therefore lobar in type. But lobar pneumonia is rare in comparison, and, indeed, the four patients in this study might possibly have had some process in both lungs had our use of the stethoscope been more experienced. All fatalities showed bronchopneumonia. Moreover, most of the bronchitis cases were of the sudden, acute, bilateral type. The explanation of this group we believe is either irritation on top of a preëxisting lung disorder or fine aseptic emboli showered in from the operative field.

Beyond these three chief factors lie other predisposing and accessory factors, as the general state of the patient, his age, appearance and cardiorenal condition. We know that ether produces an acidosis (Frank⁵³). Does the circulation back down during operation, giving poor lung circulation and a favorable field for organisms already present (Whipple³)? How much does this acidosis lower the general resistance? Hamburger⁵⁴ of Gröningen has shown that if marked it reduces the phagocytic power of the leukocyte. We know that only 40 per cent of our patients were at an age when the risk begins to be considered serious. Of the fifty-five cases reported, thirteen can be called good risks, twenty-nine fair, and only thirteen poor risks.

53 Frank, L. Surg., Gynec & Obst 30 185 (Feb) 1920

54 Hamburger, H J Brit M J 1:37 (Jan 8) 1916

We agree, of course, that a poorly administered ether anesthesia with a wet, blue patient, who vomits during the induction or constantly inhales mucus, may be the direct cause of a pulmonary complication, but this does not explain the great group of such cases. Possibly chilling, too, plays a rôle, whether it is exposure in the preparation (Homans,²⁶ Keen,²⁵ McKesson²⁵ and Kelling¹⁶) or chilling of the body cavities with cold packs (Armstrong,⁶ Kelling,¹⁶ Bibergeil¹²) or exposure after operation. Curiously, males are more susceptible than females, and it has been suggested that this is again a vasomotor factor, in that men are accustomed to wearing heavy underclothes, and that the change to thin hospital nightgowns is a greater exposure to them. There is one other factor about which there has been much dispute. Hoelscher³² and Kelly³¹ demonstrated experimentally the aspiration of mucus during anesthetization, and there has been much written about the role of oral sepsis (Turner²⁶). We can only say that in our experience this factor is of minor importance. The type of patient admitted to the public wards of this hospital exhibits often poor teeth which may be necrotic and carious with much pyorrhea. If oral sepsis was a dominating factor, we should expect a far higher incidence, whereas patients with clean mouths often develop these complications.

SUMMARY AND CONCLUSIONS

Postoperative pulmonary complications constitute a serious menace to any patient who submits to operation. Reliable statistics show that one patient in from every thirty to fifty patients operated on, no matter what the anesthetic, develops a pulmonary complication, and one patient in from every 150 to 175 patients dies from some such complication. The factors responsible for this are complicated and not always preventable, but an understanding of the mechanism suggests prophylactic measures.

We believe that embolism from the operative field is the chief factor in the etiology of such complications. It is favored by (1) sepsis, (2) trauma, and (3) the mobility of the part. Other factors of varying importance are preëxisting lung disease, the irritation of the anesthetic and such general factors as old age, chilling and poor general condition. Such embolism may occur immediately during the operation or during the convalescence, and may be the cause equally of pneumonia, bronchitis, pleurisy, empyema, lung abscess or fatal pulmonary embolism. Embolism in the sense we use it includes the transfer of small particles which may or may not be sterile from the

55 McKesson, E. I. *Am J S (Anesthesia supp)* **32** 16 (Jan) 1918

56 Turner. *Proc Roy Soc Med*, 1912-1913, *Odontological Sec*, 79

operative field to the lungs by either the lymphatics or blood channels. We do not presume to state that this is the sole cause or always the chief etiologic factor. And in accord with the previous study of one of us² and the reports by Whipple,⁸ we believe that inhalation anesthesia on top of an existing lung lesion may in some cases be the dominant factor.

The following prophylactic measures are suggested: (1) a reduction in operative trauma in an effort to produce as few and small thrombi as possible, (2) every effort in septic cases to prevent further extension of infection so that bacteria will not be present in the blood stream, nor sepsis aid in the setting free of thrombi, (3) to avoid, if possible, operating on patients with an existing lung lesion, however slight, (4) avoidance of chilling both by cold packs in laparotomies or by widely gaping wounds and by exposure after operation, and (5) to make each case before operation as good a risk as that individual case can be made.⁵⁷

Undoubtedly, all surgeons try to carry out these obvious prophylactic measures. There is evidence that pulmonary complications follow even the simplest operations in the best hands, but the weight of evidence is overwhelming that serious pulmonary complications can be prevented to a large extent if such measures are appreciated and carried out in detail.

⁵⁷ In addition to the references already given, the following will be found of interest:

Birtch, F. W. *California State J. M.* **16** 200 (April) 1918.

Gerulanos. *Deutsch. Ztschr. f. Chir.* **57** 382.

Henle. *Arch. f. klin. Chir.* **64** 339, 1901.

Robb and Dittrick. *Surg., Gynec. & Obst.* **3** 51, 1906.

THE SECOND GREAT TYPE OF CHRONIC ARTHRITIS

A LABORATORY AND CLINICAL STUDY *

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Under this head, I include the cases described under many different names and by numerous writers, e. g., arthritis deformans (German), osteo-arthritis (English), hypertrophic arthritis (Goldthwait), degenerative arthritis (Nichols and Richardson). This is the so-called senile form of arthritis, the "chronic rheumatism" of the elderly, the metabolic form of arthritis. Other writers have employed other terms, almost without number.

The subject is a most confused one, so confused that, in reading an article, one is often at a loss to understand the author's meaning, whether he is really discussing this disease or one entirely different.

Generally, the name employed is one that describes the characteristic which the author deemed most important, but it often turns out to be a misnomer in the light of subsequent investigation, and is thus a source of confusion. Thus "arthritis deformans," a mixture of Greek and Latin, means different things to different people¹. Again, any severe joint inflammation may be a deforming one. Osteo-arthritis means simply an inflammation of bone and joint. Hypertrophic arthritis describes well the most prominent feature of the roentgenogram, but, as I shall attempt to show, and as others before me have indicated, bone atrophy far exceeds bone hypertrophy in this disease and is really its characteristic pathologic feature.

The term degenerative arthritis was chosen because the originators of the term considered the degeneration of the cartilage to be the primary change, whereas it is almost undoubtedly the result of changes deep in the bone. Senile arthritis would usually apply, but the disease occasionally occurs as early as the third decade. The term "metabolic arthritis" means nothing at all.

Eventually, our classification of the arthritides will probably be on an etiologic basis exclusively, but our knowledge at present does not suffice for this, and in the meantime it is well to adopt a nomenclature that will prevent confusion.

* From the Leland Stanford Junior University Clinics and Laboratory of Surgical Pathology.

¹ Byfield, A. H. The Etiology of Arthritis Deformans in Children, *Am J Dis Child* 19:87 (Feb.) 1920. The author evidently is discussing a disease entirely different from that originally described as arthritis deformans.

All cases of chronic arthritis fall naturally into two classes, or types those which do not show spurring at the lines of insertion of the capsule, and "lipping" at the circumference of the articular cartilage, and those which do show this spurring and lipping The first type includes tuberculous, gonorrheal, syphilitic, typhoid, diplostreptococcic joints, etc The second includes the joints under discussion Tabetic joints are not included

My clinical material consists of the ninety patients whose histories are abstracted here, who were seen during the last five years at the Stanford clinics

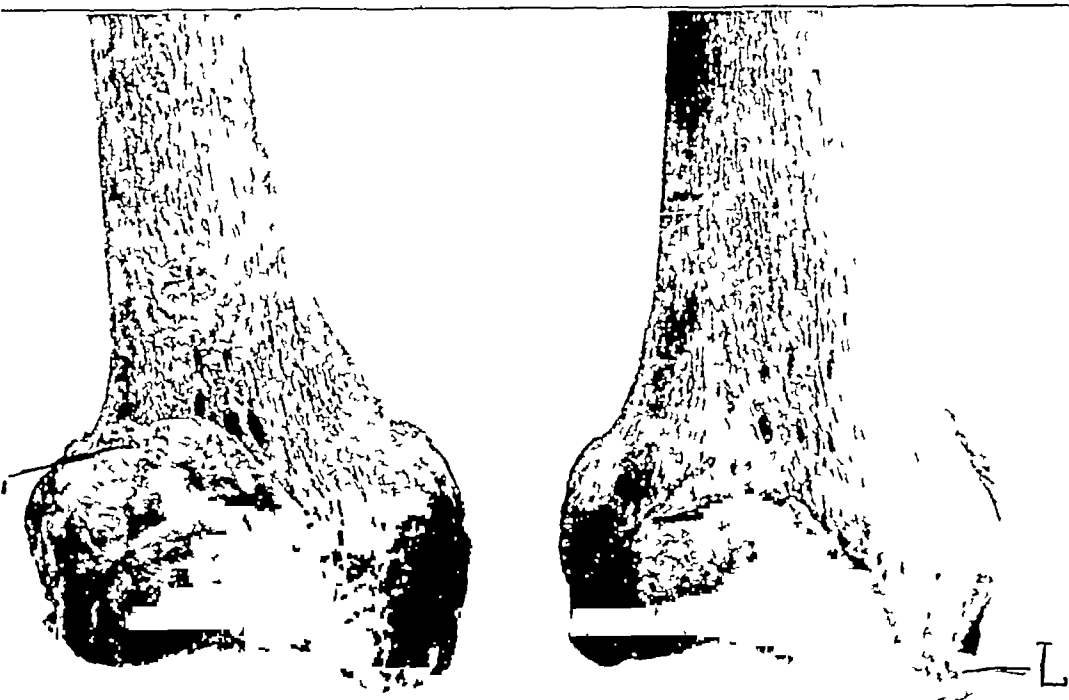


Fig 1—The lower end of two dried femurs, showing typical lipping at the joint circumference

The diagnosis was made tentatively by clinical examination and was established by the roentgen rays If the roentgenogram showed bony spurs or "lipping" of the joint the case was included in the list, if it did not, the case was thrown out Positive evidence of bone formation at the joint line was the criterion (Fig 1)

My pathologic material consists of fragments removed from many joints at operation and of four femoral heads and one knee joint gained by resection and described herewith These were fixed in liquor formaldehydi or alcohol and sections were carefully made Sec-

tions were decalcified in 5 per cent nitric acid, run through the alcohols and ether, embedded in celloidin or a substitute cut with a microtome, stained with hematoxylin and eosin, and with the van Gieson Giemsa and Gram-Weigert stains. Specimens 225, 227 and 229 were taken immediately after removal at operation to the bacteriologic laboratory for investigation,² and cultures were made from them forthwith, that is, within ten minutes after removal.

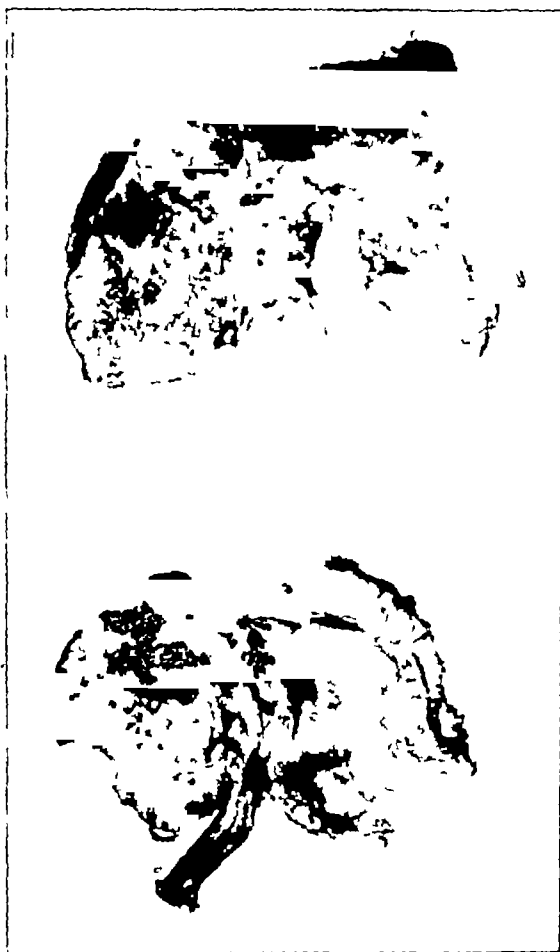


Fig 2—Typical joint surfaces in second type of arthritis, distal end of femur and proximal end of tibia

PATHIOLOGY

The joint changes of this type of arthritis have been well described especially by Nichols and Richardson³

The gross changes are cartilaginous and bony lipping at the circumference of the joint, with bony spurs at points of insertion of the

² The bacteriologic work was done in the bacteriologic laboratory of the Leland Stanford Junior University School of Medicine

³ Nichols and Richardson Jour Med Research **21** 150, 1909

capsule, thickening of the cartilage, then calcification and erosion, leaving the underlying bone bare, condensation of this bone (eburnation) with grooving in the line of joint motion, hypertrophy of the synovial membrane, with marked villous formation and frequently fluid in the joint

Adhesions between the bone ends never result from these changes, as they do in the first type of arthritis (tuberculous, syphilitic, gonorrheal, etc.), and the limitation of motion is caused solely by distortion of the ends of the bones (The bony ankylosis in the spine forms an exception to this rule) The joint is mechanically damaged

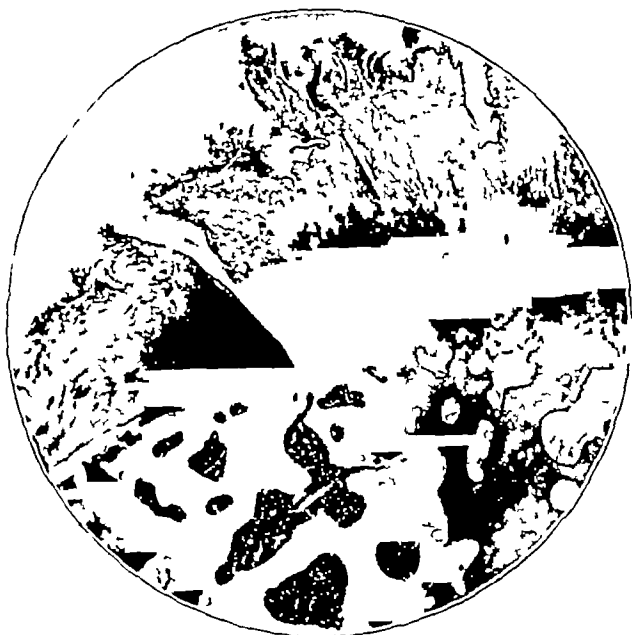


Fig 3—Low power photomicrograph of stained section showing typical fibrillation calcification and tattering of cartilage

Nichols and Richardson regard the cartilage changes as the primary and characteristic feature of the disease They observed rarefaction deep in the bone, and noted cyst formation for which they were unable to account, except possibly that it resulted from the atrophy of disuse

Ziegler⁴ calls attention to the bone rarefaction and cysts, and regards them as most significant Wolkoff⁵ thought the cysts were the direct result of trauma

Under the microscope, the changes in the cartilage are most prominent (Fig 3) Its cells are swollen and in groups It presents a

⁴ Ziegler, Ernst Lehrbuch der allgemeinen Pathologie und der pathologischen Anatomie Jena, Gustav Fischer 2 1906

⁵ Wolkoff Verhandl der deutsch path Gesellsch 9 229, 1905 Kimura Beitr z path Anat u z allg Path 27 223 1900

tattered, irregular and often bizarre appearance (Figs 4 and 5) Later it disappears and leaves the thickened subjacent buttress of bone bare, though islands of it may remain The bony thickening is suggestive of Nature's attempt to wall off the marrow from the joint (Fig 6) The thickened synovial membrane consists largely of fat and loose meshed fibrous tissue The villi do not possess the lymphoid appearance common to the members of the first group

Areas of cellular infiltration are frequent in the synovial membrane (Fig 7)

The marrow is often fatty and fibrous, as one would expect in elderly people It contains minute spicules of bone and cartilage,

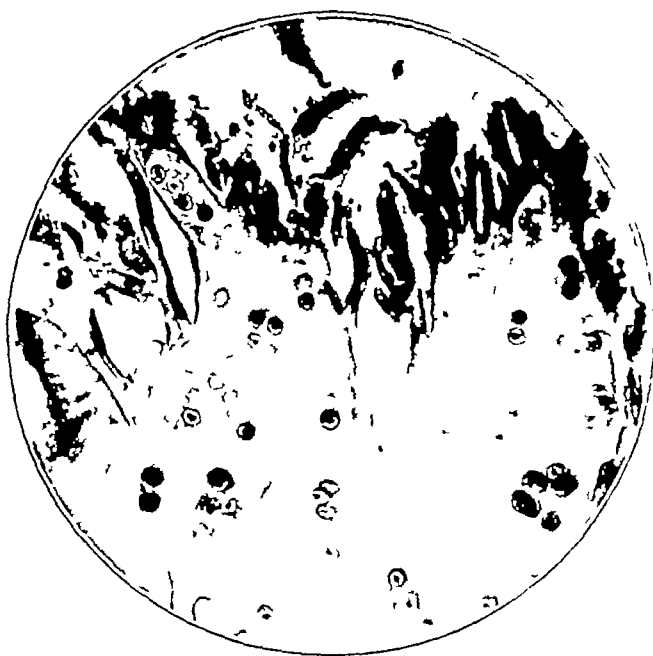


Fig 4—High power photomicrograph of a portion of stained section shown in Figure 3

and the bone trabeculae close to the joint are increased in number and thickness Areas of cellular infiltration, sometimes composed largely of plasma cells, are a prominent feature (Fig 8) Rarefaction of the bone begins a short distance from the joint line, and is a constant and prominent feature This rarefaction is plainly evident in the roentgenogram

Distinct, irregular cavities were present in five of my specimens The fifth, the head of a femur, was little else than an aseptic sequestrum These cavities may present the typical appearance of cysts, they may be filled with fibrous tissue, or they may contain dead bone and other necrotic material Their presence could not be detected by the

roentgen ray In one case, however, that did not come to operation, a typical cavity, with a sequestrum, could be seen in the lower end of the femur

Four years ago, I called attention to the cavities, seen by the naked eye, in dry bones presenting this type of arthritis ⁶

DESCRIPTION OF SPECIMENS WITH CASE HISTORIES

SPECIMEN E 187—*History*—The patient, a widow aged about 55, had suffered pain in the right thigh for ten or twelve years This recently had become much worse until at the present time she can hardly walk The mode of onset was unknown The patient was healthy otherwise. She had had no trouble with the throat, all her teeth had been extracted ten or twelve years before.

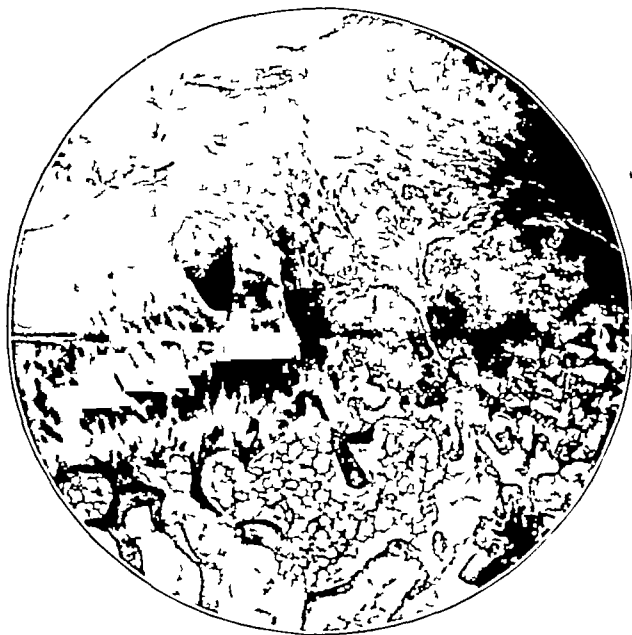


Fig 5—Low power photomicrograph showing irregularity in structure and outline of the joint cartilage New bone formation going on beneath it may be noted

She had had nine children, three were dead, one was stillborn, one died of diphtheria, and one died at 7 months The patient limped, the right hip being in slight flexion abduction and external rotation The thigh muscles were atrophied Flexion was slightly limited, other motions were markedly so There was no Kernig nor Ely sign The spine was rather stiff

Treatment and Results—Resection of the hip was performed through an anterior excision followed by a plaster-of-Paris spica for six weeks Thirteen

⁶ Ely L W A Study of One Hundred Dry Bones Sawed in the Laboratory Bone and Joint Studies I Stanford University, Calif, 1916 published by the Leland Stanford Junior University

months after operation, the patient walked fairly well, with a marked limp, but with little pain. The hip was in slight flexion and possessed a range of motion of 40 degrees (estimated). Abduction was slightly limited. The limb was 3 cm shorter than the other.

Examination of Specimen—The specimen consisted of the head of the femur and fragments from the acetabular rim. The joint surface of the femur jutted out over the neck inferiorly, so as to give the impression of an impaction of the neck into the head. In its central portion the head was partly eburnated, and partly covered with soft granulation tissue. Its circumferential portion was covered by cartilage, which was more or less roughened and fibrillated. In the acetabular fragment were two small cavities just beneath the cartilage.

Section of the acetabular fragments revealed the usual changes of the second type of arthritis. Section of the head in line with the neck revealed two or three cavities close to the joint line. The bone cut hard.

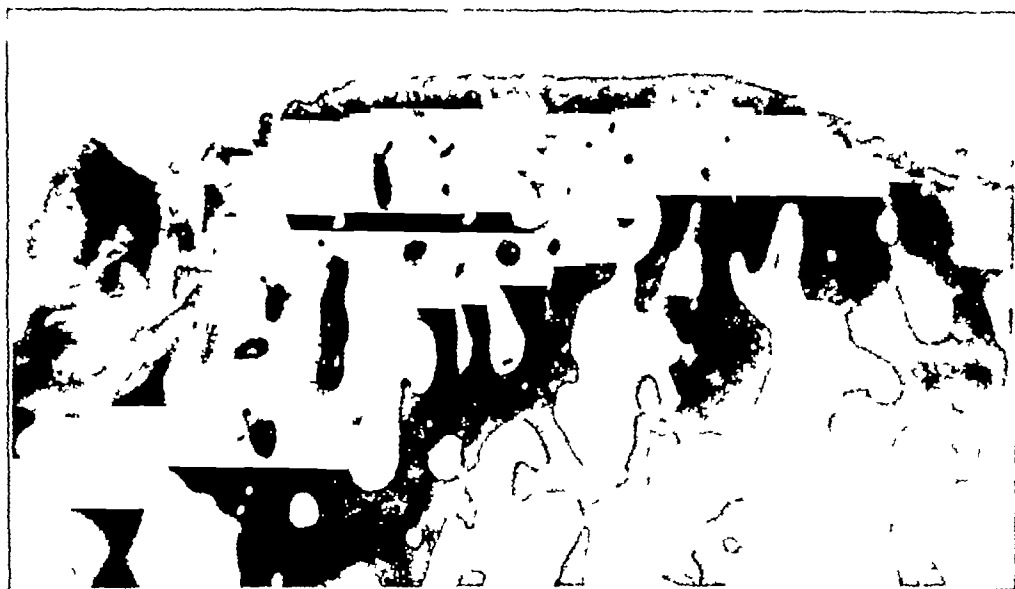


Fig 6—The eburnated bone at the joint surfaces, low power photomicrograph

Histology—Head (Figs 9 and 10). At and near the surface was an irregular layer of dense bone about 5 mm thick, which thinned out rapidly, so that at the depth of about 1.5 cm the bone was more spongy than normal (Fig 9, D and R). The cartilage was gone, except at the side, where it was thick, more or less split up, fibrous (fibrocartilage), and, on its surface, tattered. Its cells were swollen and rather transparent, and some of them had lost their nuclei. Here and there, islands of cartilage were seen on the joint surface, not lying on the bare bone, but rather in it.

The outstanding feature was the presence of cavities of greater and smaller size in the dense bone near the articular surface. Some of these were filled with fibrous tissue, rather dense, some contained necrotic tissue and dead bone, about which was a fibrous capsule. Here and there, masses of fibrous tissue intersected the dense bone at the articular surface. When they did, the adjacent bone had the bitten out appearance characteristic of rarefying osteitis, and yet new bone apparently was being developed, in this situation in

most instances directly from fibrous tissue, but here and there from cartilage. Part of the dense bone at the surface was dead. This could be determined not only by its empty lacunae, but also by its different reaction to stains.

The marrow near the joint consisted of little else than dense fibrous tissue. Deeper in, the marrow was fatty, and still deeper, some lymphoid marrow appeared. It was well supplied with blood vessels. No organisms were found in sections stained with Giemsa and Gram-Weigert stains.



Fig 7—Low power photomicrograph of joint capsule, showing the thickening of the synovial membrane and its cellular infiltration at X

SPECIMEN E 168—History—A man, aged 42, who had been operated on for fistula in ano nine years before (a histologic examination of the tissue is said to have revealed tuberculosis), whose spine and wrist had been treated eight years before for tuberculosis, with plaster jackets and passive hyperemia, recently had had trouble in the knee, and the joint had been injected with liquor formaldehydi and glycerin.

Operation—Resection of the knee was performed at the San Francisco Hospital. The specimen included the patella, the upper end of the tibia and the

lower end of the femur, with soft parts. The bacteriologic examination made at the San Francisco Hospital is said to have revealed acid fast organisms identified as tubercle bacilli.

The synovial membrane was injected, hypertrophied, succulent and villous. The bone ends were badly damaged, and showed lesions of Type II. The patella was badly scarred on its posterior aspect, which consists largely of fibrous tissue, and showed no bare bone. A tuft of villous synovial membrane covered its distal portion.

Both femoral condyles showed border exostoses, and eburnated areas. The lateral condyle had a defect on its surface, about 1 cm. in diameter, and its anterior portion was crossed by an oblique groove, anterior to which was a



Fig 8—Low power photomicrograph, showing cellular infiltration in the marrow.

ridge of cartilage and bone. There was a deep, eroded groove still more anteriorly on the medial condyle. The anterior surface of the lower end of the femur was irregular, and badly eroded.

The articular surface of both tibial tuberosities was eburnated in places. Border exostoses were not so prominent as in the femur. The medial tuberosity showed one large defect, the lateral, two smaller ones. A band of adhesions ran across the lateral tuberosity, between the soft parts on either side.

A section was made of the end of the tibia. A number of cavities were found close to the articular surface (Fig 11).

Histology—Over one side of the slide the joint cartilage showed the typical changes of the second type. It was split up, irregular and tattered. Many of its cells were absent, much of it was dead.

The cartilage of the other side was gone, and had been replaced by connective tissue, which in places had all the appearances of synovial membrane. Under this was a fairly well defined layer of rather dense trabeculae, irregular on the surface and unlike the dense, eburnated, fairly smooth bone which is usually seen. Beneath this, the bone and marrow appeared fairly normal. The latter was fatty and contained some lymphoid tissue, but was well supplied with blood vessels.

Beneath the other part of the joint, where the cartilage remained, there appeared the characteristic cavities, three or four in number, fairly distinct from one another, well walled off by bone on their joint side, and fairly well walled off on their other sides. These were filled with fibrous tissue, the greater part of which was quite dense. In the center of one was some hyalin, which was surrounded by concentric layers of fibrous tissue. In this limited area there were no blood vessels. The blood vessels were abundant in other parts of the marrow.

Rarefying osteitis was present to a limited extent, but no dead bone could be seen anywhere.

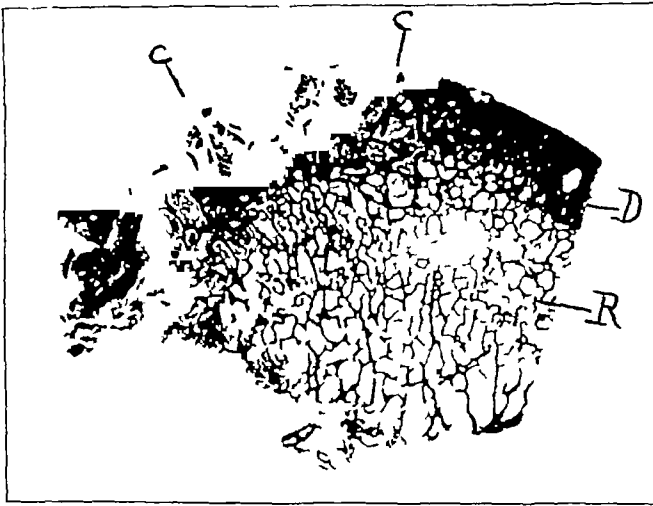


Fig 9—Low power photomicrograph of stained slide from Specimen E 187 dense bone at and near the articular surface, with cavity formation (C C) may be noted.

There was no evidence of tuberculosis. The slides on which the diagnosis of tuberculosis was based were secured, and no tubercle bacilli were found.

Sections stained with Giemsa and Gram-Weigert stains were negative for organisms.

SPECIMEN E 225—History—A rancher, aged 64, who had complained of pain in his right hip for twelve or fourteen years, the onset of which had been slow, no history of injury could be obtained, had pain in the right knee also. After much trouble with his teeth, the patient had had them all extracted fourteen years before.

Examination—The patient was a large, heavy-set, broad-backed man of the so-called "herbivorous" type, who walked with a moderate limp. The right lower extremity was apparently short, and was in a position of slight flexion,

and marked external rotation. All motions in the hip were decidedly limited. When flexion was forced the thigh went into abduction—fairly characteristic of this form of arthritis.

There was no actual shortening, although there was an apparent shortening of $1\frac{1}{2}$ inches. The roentgenogram revealed the typical changes of an arthritis of the second type, with marked rarefaction of the head and neck (Fig. 12).

Operation—Feb. 2, 1920, I performed resection of the hip, using the Smith-Peterson incision. The head of the femur was sent to the bacteriologic laboratory. The wound was sutured without drainage. A plaster-of-Paris spica was applied for two months, then crutches and physical therapy were used.

Examination of Specimen—This consisted of the head of the femur and fragments of the acetabulum. In the proximal posterior part of the head, rather close to the joint surface, was a cavity about 2.5 by 1.5 by 1 cm. in diameter, filled with a gelatinous material (Fig. 13 C). It was situated about 2 or 3 cm. from the attachment of the ligamentum teres. It had rather dense walls.

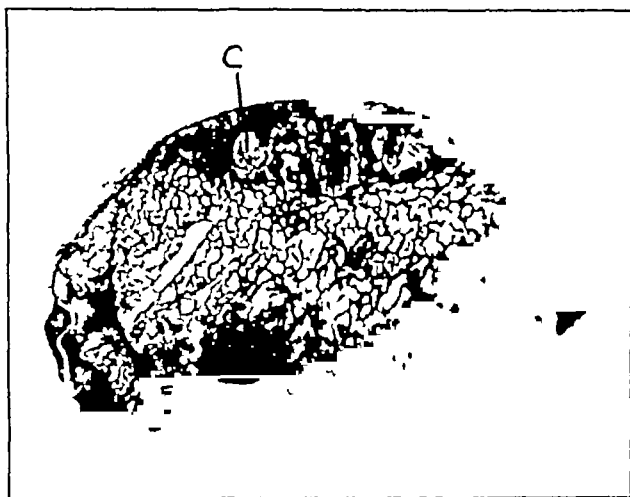


Fig. 10—Low power photomicrograph of stained slide, from a section taken at a distance of 5 or 10 mm. from the section shown in Figure 9.

The joint surface showed the usual changes of the second type of arthritis, with eburnation. A band of soft, pink granulations, about 1 cm. wide, passed across it.

A section of the head through the cavity revealed a number of other cavities filled with gelatinous material. The stained slide (Fig. 14) presented to the naked eye a marked irregularity of structure of bone and cartilage. The articular surface was divided into two portions. On one portion the cartilage was fairly thick, and was calcified in its deeper layers. At its extremity, it contained bone in its interior (Fig. 14, B). The cartilage was absent from the surface of the other portion.

Several large, irregular cavities (Fig. 14 A, E, F) besides the one on the margin of the specimen which was scooped out for culture (Fig. 14 C), were found in the bone near the articular surface. These were crossed by strands of fibrous tissue. As a rule the bone was fairly dense near the joint.

Histology—The articular cartilage, present on one side of the articulation, was degenerated, fibrillated, irregular in outline, and stained deeply with

hematoxylin in its deeper portion. Calcified, necrotic masses could be seen in its interior. At its periphery a layer of new bone was being formed in its interior. This evidently formed the characteristic border exostosis or lipping.

On the other side of the articulation, a rather thin layer of dense, eburnated bone was found. This, broken up by occasional patches of fibrous tissue and cartilage, continued entirely across to the other side of the section.

When a number of slides were studied one saw several cavities. These differed in number, shape and size, as well as in contents in the different sections. One slide near the joint surface showed little else than a succession of these cavities for about two thirds of its extent. Another would show only two or three. Some of these cavities were typical cysts or collections of cysts, others contained nothing but fibrous tissue.



Fig 11—Low power photomicrograph of stained slide from Specimen E 168. The arrows point to two cavities in the bone.

The large multilocular (Fig 14 A) cyst contained a little detritus, in which were a few spicules of dead bone. The fibrous strands that crossed it contained both live and dead bone.

Near the large multilocular cyst was an elliptical cavity (Fig 14 E). This had a well defined capsule of fibrous tissue and a fairly well defined bony wall. It lay under the rift mentioned before. This rift was filled with fibrocartilage. At the side of this elliptical cavity was seen an irregular mass of fibrous tissue (Fig 14 F). In other slides, this was much larger, was well walled off by dense bone, and was quite vascular. It replaced the elliptical cavity. In other words, part of this large irregular cavity, cut across at different levels, was filled with fibrous tissue, another part was cystic.

The marrow was as a rule fibrous near the joint, and the trabeculae in this locality were evidently undergoing absorption. Deeper in, the marrow was fatty.

Cultures from the cavity made at operation, were negative. Sections stained with Giemsa's and Gram-Weigert stain, were negative for bacteria.

SPECIMEN E 227—History—A farm hand, aged 33, who for the last twelve years had complained of pain and stiffness of both hips, the pain having begun gradually, and having grown worse, with no history of injury, who had had no sore throat, but had had much trouble with his teeth, was referred to the dental clinic, and his infected teeth and buried roots were removed.

The roentgen rays revealed marked changes of arthritis of the second type in both hips, with rarefaction in the head and neck of the femur (Figs 15 and 16).

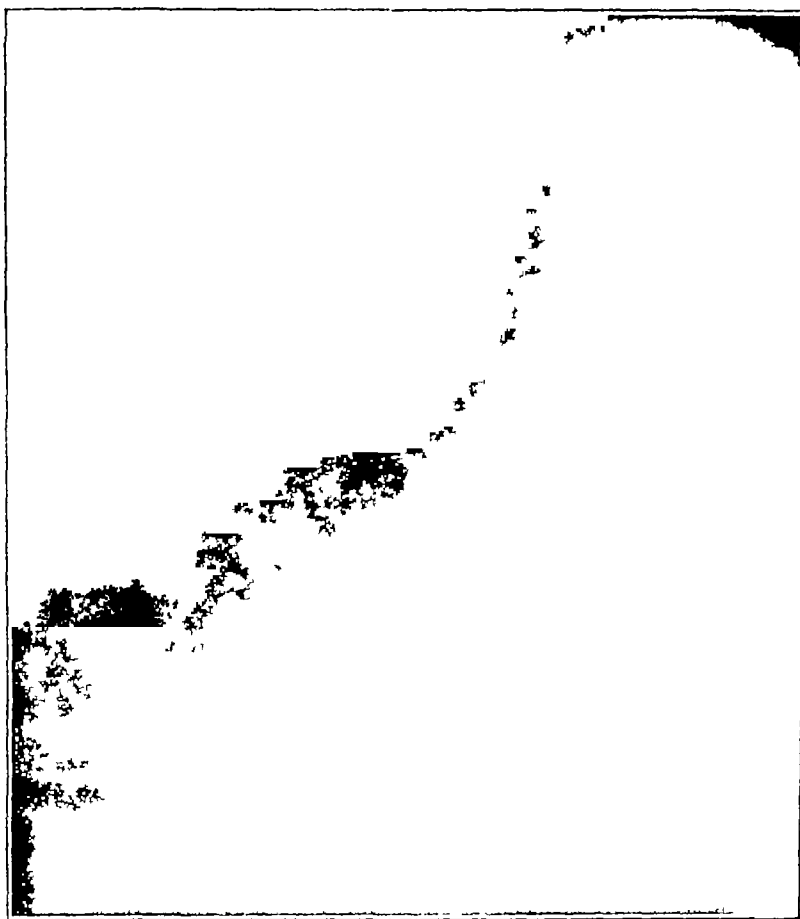


Fig 12—Hip described under Specimen E 225

Both hips were in slight flexion and external rotation. The left was in adduction. All motions in both hips were limited, but each possessed a small range of painless motion. The left hip appeared to be involved to a greater degree than the right. Resection of this hip was advised.

Operation and Results—March 5, 1920, resection of the left hip was performed, the Smith-Peterson incision being used. The head of the femur with part of the proximal border of the acetabulum was removed. The wound was sutured in layers. The head of the femur was taken immediately to the bacteriologic laboratory for cultures. A long plaster-of-Paris spica was applied from the axillae to the toes.

The plaster-of-Paris spica was removed on April 14, and the patient was permitted to go about on crutches

Examination of Specimen—The articular surface of the head presented the usual changes of arthritis of the second type, but without much eburnation. In the posterior part of the head, about 0.5 cm from the joint line, a large irregular fusiform cavity about 1 by 1 by 2 cm in diameter was found which was surrounded by rather dense bone, and filled with dense fibrous tissue which was removed with great difficulty (Fig 14 C). It was firmly adherent to the bone.

A section of the head was made through the cavity.

The stained section of the head presented somewhat the appearance of a mushroom, the stalk of which was formed by dense bone, which had a more or less lamellar arrangement, and almost the density of cortical bone (Fig 18).

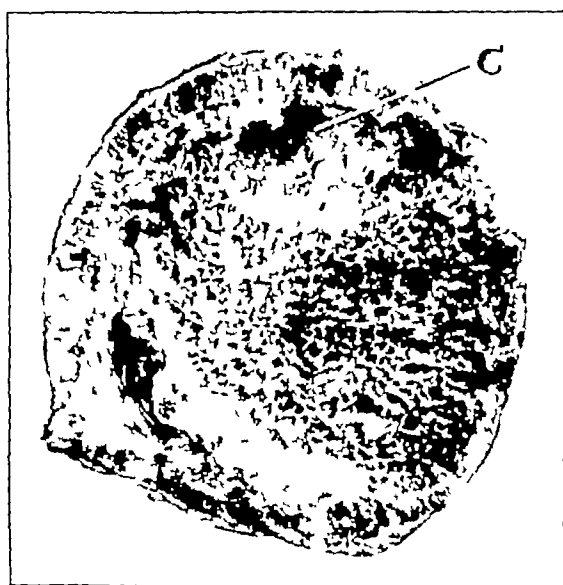


Fig 13—Specimen E 225 at line of section from neck of bone, showing cavity at C

The space on one side of this (G) was an artefact, caused by gouging out the bone for cultures. (It was so soft that it was gouged out with a scalpel). On the other side was the cavity noted heretofore (Fig 18 C).

The wall of the bone of the central stalk, as well as the spongy bone on the rest of the wall of the cavity, showed remnants of the fibrous tissue which was removed for bacteriologic examination, and for separate study. In this fibrous tissue were small spicules of bone, most of them dead.

The marrow throughout the specimen was almost exclusively fatty, and contained many thin-walled vessels and "blood spaces," filled with blood. This gave it the appearance of the marrow of an animal that had died of an infectious disease.

The bone trabeculae were somewhat thickened near the joint surface, but not so much as is usually the case in this type of arthritis. They presented the classic appearance of "productive osteitis," being lined by osteoblasts.

The articular cartilage was thin, irregular and degenerated, but it covered the bone completely, except for one or two small areas.

The contents of the cavity consisted of dense fibrous tissue containing necrotic material. Here and there one could see areas of calcification, and spicules of dead bone.

Cultures from the material removed from the head were negative. No bacteria were found in the stained specimen.

The guinea-pig test was negative.

SPECIMEN E 229—History—A laborer, aged 52, for four years had suffered pain in the left hip which he dated from an injury—a "lot of sacks" having fallen on the hip.

Examination—The patient limped badly. The left hip was in slight flexion and adduction. Extension, rotation and abduction were limited, flexion was

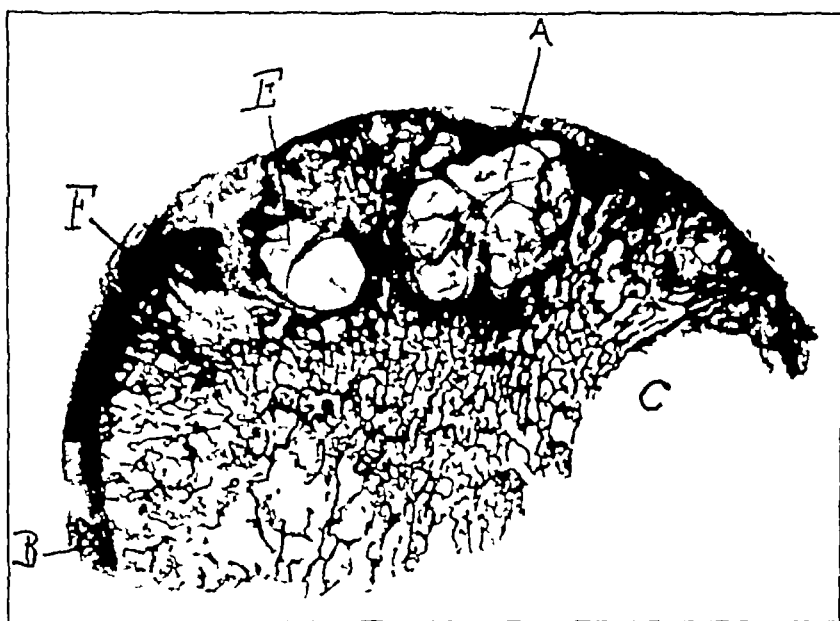


Fig 14—Low power photomicrograph of stained slide from Specimen E 225 C, cavity shown at operation.

free. Ely sign was positive. The hip went into abduction when flexion was forced. There was moderate muscular atrophy.

The skiagram revealed the typical changes of the second type with much rarefaction in the head and neck (Fig 19).

The patient also had a well-marked Dupuytren's contraction in both hands.

Operation and Results—March 13, 1920, resection of the hip was performed with the Smith-Peterson incision. The joint contained fluid, which was aspirated and sent with the femoral head immediately to the laboratory for cultures. The wound was sutured in layers with catgut. A plaster-of-Paris spica was applied from the nipples to the toes.

April 3, the plaster was removed from the foot. The patient commenced to walk with crutches. April 8, the plaster was removed from the leg. April 21, it was entirely removed. April 23, the patient left the hospital, walking with a cane.

Examination of Specimen—The joint cartilage had a deep wrinkle, like that on an old man's skin, running across it, and in the neighborhood of this wrinkle it was detached from the bone. It appeared as if it could be rubbed off. Lipping was present at the circumference of the joint. There was no evidence of cavities in the bone.

The head was sawed in sections about 5 mm thick (Fig 20). It presented a most remarkable appearance. It looked as if it had been fractured near the joint, though the solution of continuity was not complete, and the fragment was still partly attached. Softened areas, dense bone and spongy bone all were seen.

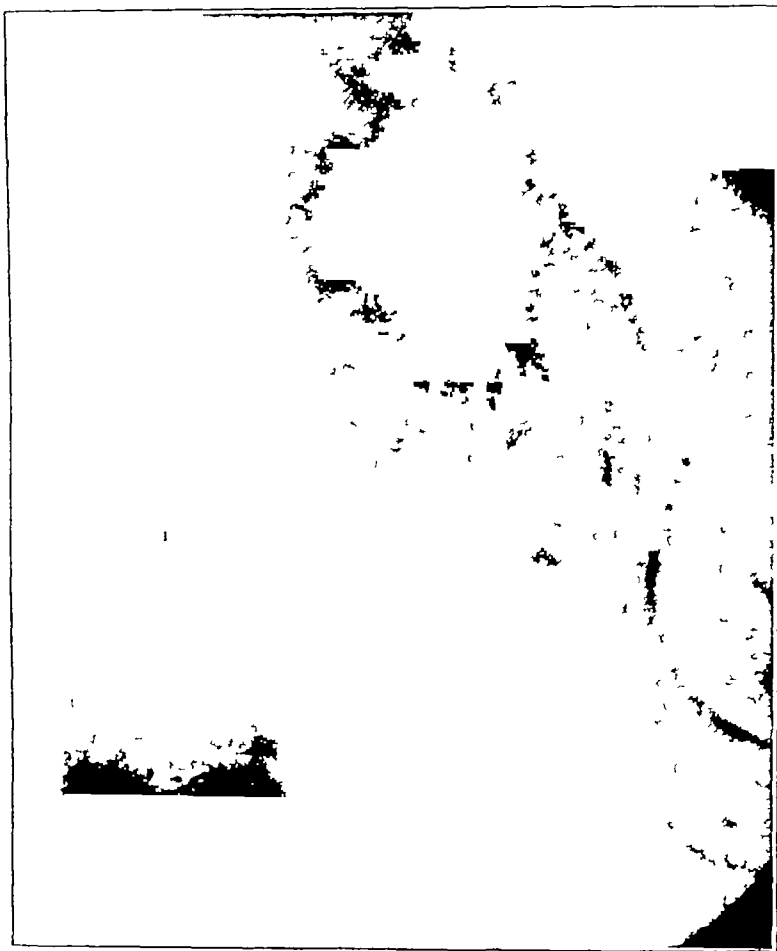


Fig 15—Left hip described under Specimen E 227

Histology—A section when stained (Fig 20 A and Fig 21) revealed areas of necrosis, and patches of calcification. Much of the bone was dead, but some was alive, and where there was live bone the marrow consisted of fibrous tissue. Elsewhere the marrow as well as the bone was dead. The head, in other words, was practically a large sequestrum.

The fractured piece was dead (Fig 21 S) and the irregular line of fracture was bounded on both sides by dead bone.

The cartilage was thick, irregular, degenerated and showed marked calcification. At one side, it was overlaid by a new formation of bone and cartilage—the typical lipping (Fig 21 L).

Cultures from the head and from the joint fluid were negative. Examination of the stained specimen revealed no bacteria. The guinea-pig test was negative.

COMMENT

These five specimens present two features in addition to the typical bone production at and near the joint line and the cartilaginous changes usually described: (1) rarefaction of the bone beginning a short dis-

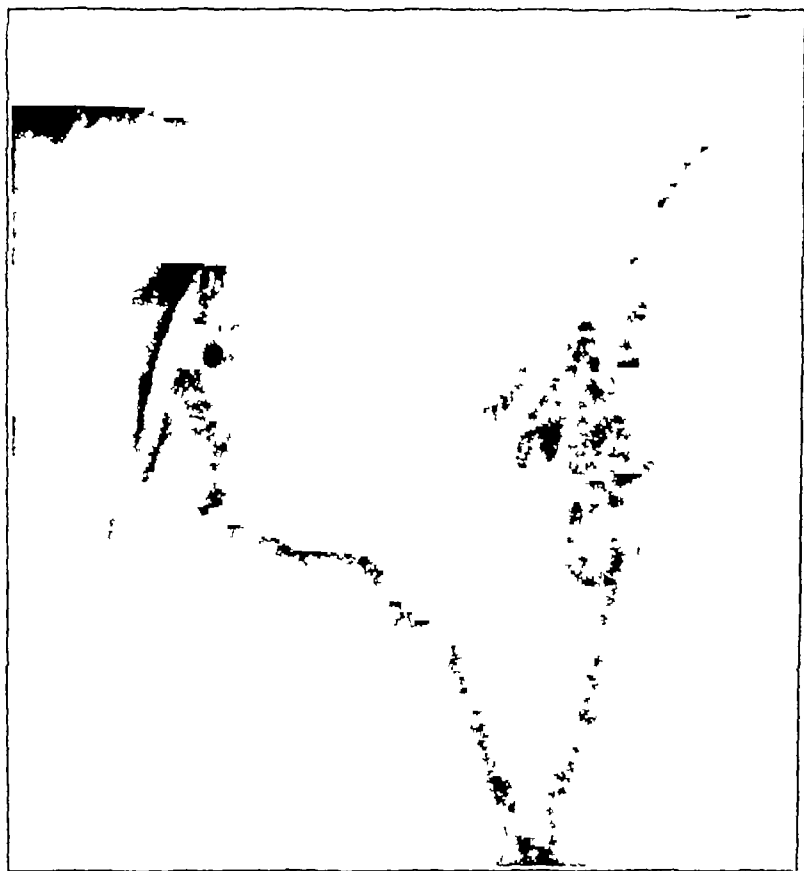


Fig 16—Right hip described under Specimen E 227

tance from the joint, and (2) softened areas with necrosis of a greater or less degree, with the exception of one specimen which showed no necrosis, but fibrous tissue filling the cavity.

Dr William Ophuls, who examined the sections without reading the histories, interprets them as forming a chronologic series. The fractured and necrotic head of the femur represents the most recent changes and the head of the femur containing the cysts (Specimen E 225) represents the latest stages of the pathologic process. This conclusion is sustained by the clinical histories.

We find, then, that the essential feature of this type of arthritis is an aseptic necrosis with cavity formation in the bone at a short distance from the joint

The agent producing this necrosis is not known. No direct evidence of infection has been found.

We must discard the theory that the changes in the articular cartilage are primary. This theory is not supported by anything that we know of regarding the relation of the cartilage to subjacent bone and marrow. On the contrary, we know that any disease in the marrow just beneath the cartilage affects its nutrition, and we conclude that in this form of arthritis, as in every other, the cartilaginous changes are secondary to those in the bone and marrow.

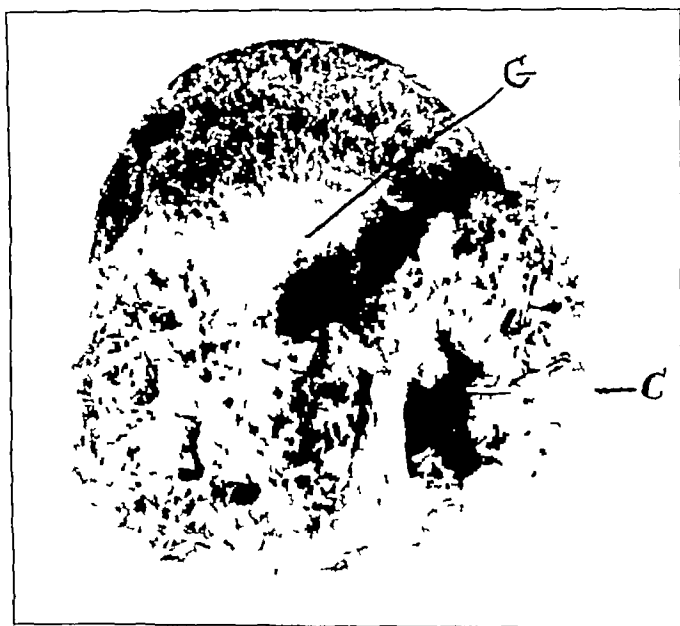


Fig 17—Specimen E 227 at line of section from neck, showing cavity at C. The cavity at G is an artefact caused by a portion being gouged out for culture.

Much the same may be said of the bone production at the joint line. While it is the distinguishing feature of the disease, the feature which enables us to make the diagnosis, it is not the essential feature. It is secondary to the rarefaction and is less in extent. There is nothing peculiar in this, for example, compare the dense bone about an old suppurative focus in the bone, or even the bone formed about an old tuberculous focus.

It is difficult to explain the synovitis except on the basis of trauma. This is the most plausible explanation. The joint is mechanically damaged, and a force that would not injure a normal joint may sprain a deformed one, that is, may injure its capsule.

In the past, almost every form of arthritis has been ascribed to trauma, but as our knowledge has increased we have found that trauma simply lights up an old preëxisting, perhaps quiescent, inflammation. This is almost certainly the case with tuberculosis.

We must bear in mind that the bone is susceptible to only one form of mechanical injury, and that is fracture. Nothing else can affect it but disease, and this is true also of the marrow. Bone cannot be strained, sprained, torn or bruised. A mechanical force fractures it or leaves it uninjured.

Most writers believe that trauma has a distinct etiologic relationship to this form of arthritis. More often there is a repeated injury or strain associated with a laborious occupation, than one severe injury. A\hausen⁷ maintained that he had produced the essential changes of

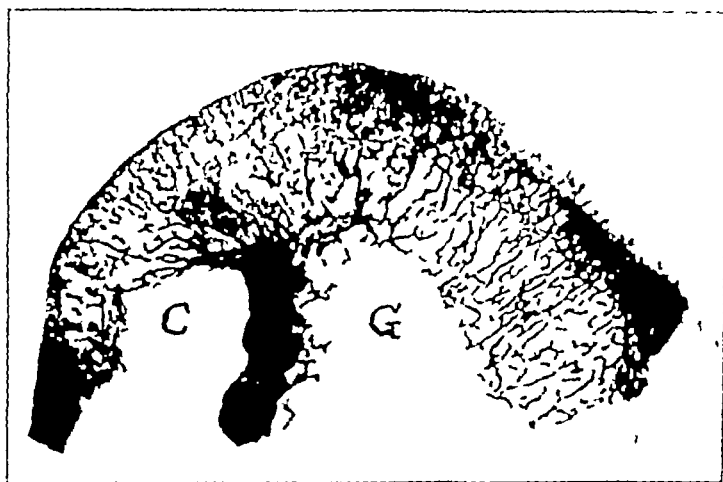


Fig. 18 — Photomicrograph of stained slide from Specimen E 227. C, cavity, G, artefact.

the disease by injuring the joint cartilage with an electric needle. It should be remembered that his electric needle would cause a necrosis of the subjacent bone and marrow. In several carefully conducted sets of experiments, John Francis Cowan and I were unable to verify his conclusions.⁸ We gouged out, in our experiments, the bone and marrow and cartilage with a sharp curet.

This disease is essentially one of advanced age. It rarely occurs under 30, and is most frequently observed after 40 years of age.

Many patients have disturbed digestion. Mental emotion has been considered by some as a causative factor.

⁷ A\hausen. *Archiv f. klin. Chir.* 99:519, 1912.

⁸ Ely, L. W., and Cowan, J. F. *Reaction of the Tissues of the Knee Joint of the Rabbit to Injury*. Bone and Joint Studies, I, Stanford University, Calif., published by Leland Stanford Junior University, 1911.

Regarding infection, no conclusive evidence is at hand, for no bacteria have been demonstrated in the fluid removed from the joints or the contents of the cysts. Our attempts at Stanford to isolate bacteria have been uniformly unsuccessful. No bacteria have been demonstrated in the marrow. It is important to make a sharp distinction between cases of this type and those of Type I. In the latter, positive bacteriologic results are often obtained.

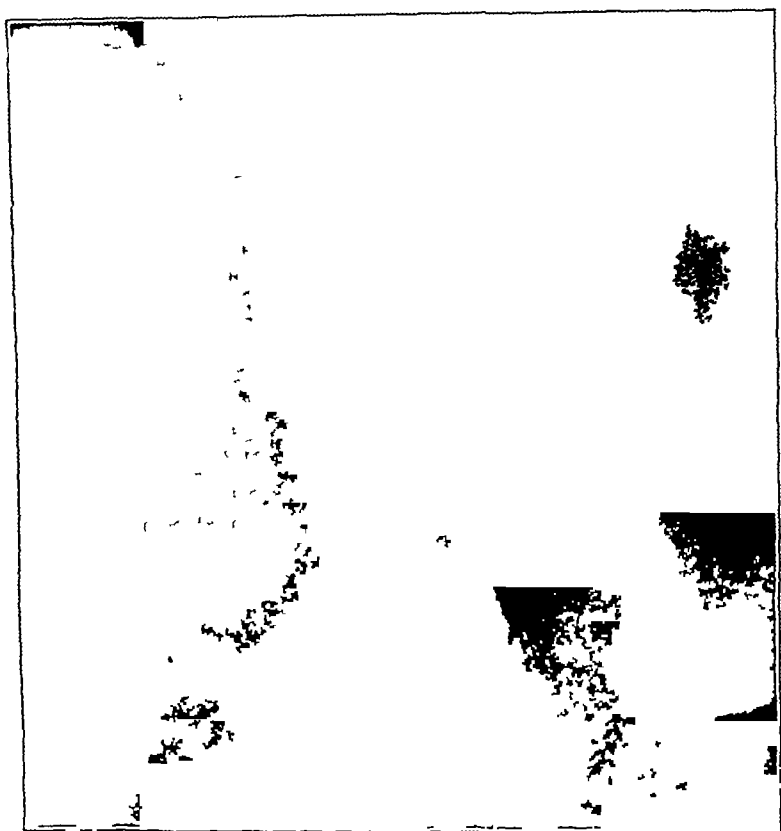


Fig 19—Hip described under Specimen E 229

SYMPTOMATOLOGY

I shall not go at length into this. The pain, stiffness, deformity, disability, muscular atrophy of a low grade form of chronic arthritis are present. The joint is usually swollen. This is due to fluid, thickening of the synovial membrane or new bone. In the hands, the disease attacks by preference the terminal interphalangeal joints—Heberden's nodes. It is frequent in the hip, spine and knee, and is often considered to be uniarticular except in the spine and fingers, but this uniarticular character is probably only apparent. Symptoms may be present in only one joint when many joints are affected.

When the spine is affected, the pain may be felt in the back, around the trunk or down the extremities, hence many complain of neuritis, lumbago and sciatica. Probably all cases of lumbago and "fibrositis" are really spinal arthritis, as well as many cases of sciatica and neuritis. We do not admit the existence of such a thing as lumbago or fleeting fibrositis in the orthopedic clinic. It is as illogical to ascribe the stiffness and pain in the back muscles, the pain in the back

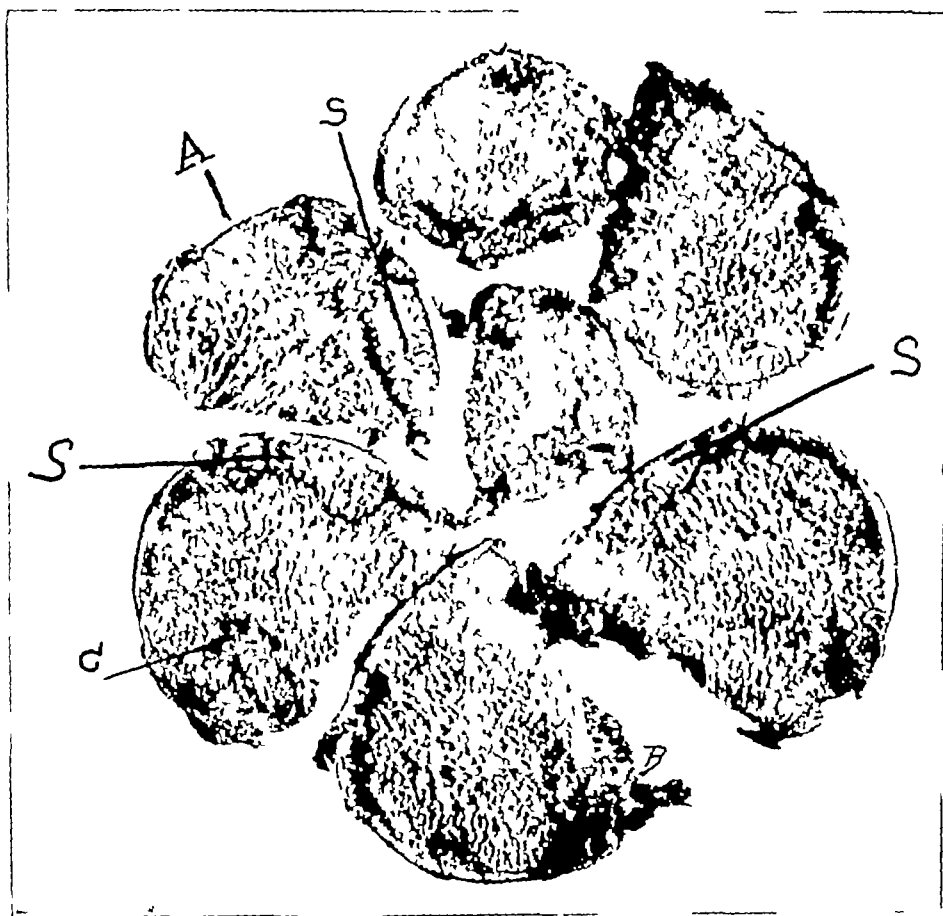


Fig 29—Sections of Specimen E 229. Section A was chosen for histologic examination, S, sequestrum.

and down the thighs to a myositis, "myalgia" or neuritis when the roentgen ray reveals distinct changes in the spinal joints as it would be to ascribe the pain in the hip, knee and thigh, and the muscular spasm about the hip to the same causes when the hip is diseased. The same condition is present in both cases. The use of the roentgen rays will determine the presence or absence of bony change in the spine.

TREATMENT

All sorts of curative means have been advocated—baking, massage, baths, external applications, internal medication, electricity, etc. Oil injections have been advocated on the theory that these joints were “dry.” They are no drier than any other. The treatment is unsatisfactory.

The accompanying table presents a short list of our clinical patients. Many of them came only once or twice, others came often enough to enable us to work up their histories thoroughly. In some, diseased tonsils were present, in some an old deep urethritis.

The alveolar infection was determined by the roentgen ray. In some instances, there was found a definite root abscess, in others



Fig 21—Low power photomicrograph of stained slide from Specimen E 229. S, sequestrum, L, border exostosis or lipping.

merely a rarefaction about the tooth. When patients submitted to extraction, the diagnosis could be confirmed. In some instances, no roentgenograms were taken of the teeth and a clinical diagnosis of alveolar infection was made.

ANALYSIS OF PATIENTS

Age and Sex—An analysis of these patients shows that sixty-eight were men and twenty-two women. The age varied from 28 to 76 years. Two were in the third decade of life, twelve in the fourth, twenty-six in the fifth, thirty-two in the sixth, fifteen in the seventh and three in the eighth. Almost two-thirds of the patients were between 40 and 60 years of age.

CLINICAL PATIENTS

Cases	Age	Sex*	Occupation	Condition	Infection
1	40	♂	Chauffeur	Arthritis, chronic, of knee	Alveolar
2	45	♂	Laborer	Arthritis, chronic, of spine	Alveolar
3	50	♂	Motorman	Arthritis, chronic, of knee	Alveolar
4	50	♂	Housework	Arthritis, chronic, of knee	Alveolar
5	73	♂	Tailor	Arthritis, chronic, multiple	Alveolar
6	53	♂	Laborer	Arthritis, chronic, of hip	Alveolar
7	33	♂	Farm hand	Arthritis, chronic, of hips	Alveolar
8	50	♂	Domestic	Arthritis, chronic, of spine	Alveolar
9	28	♂	Waiter	Arthritis, chronic, of spine	Alveolar
10	53	♂	Carpenter	Arthritis, chronic, of spine	Alveolar
11	47	♂	Laborer	Arthritis, chronic, of spine	Alveolar
12	14	♂	Sollicitor	Arthritis, chronic, of spine	Alveolar
13	57	♂	Bottle	Arthritis, chronic, of hip	Alveolar
14	40	♂	Laborer	Arthritis, chronic, of spine	All teeth out
15	67	♂	Interstainer	Arthritis, chronic, of spine	Alveolar
16	17	♂	Laborer	Arthritis, chronic, of spine	Alveolar
17	35	♂	Housewife	Arthritis, chronic, of spine	Alveolar
18	53	♂	Laborer	Arthritis, chronic, of hip	Alveolar
19	38	♂	Housewife	Arthritis, chronic, multiple	Alveolar
20	51	♂	Housewife	Arthritis, chronic, multiple	Alveolar
21	50	♂	Fisherman	Arthritis, chronic, of spine	Alveolar
22	50	♂	Rancher	Arthritis, chronic, of spine	Alveolar
23	57	♂	Laborer	Arthritis, chronic, of spine	Alveolar
24	63	♂	Carpenter	Arthritis, chronic, of knee	Teeth removed 10 yrs before 5 yrs before pain began
25	70	♂	Farm helper	Arthritis, chronic, of spine	Alveolar
26	61	♂	Cook	Arthritis, chronic, of knee	Alveolar
27	54	♂	Milker	Arthritis, chronic, of spine	Alveolar
28	61	♂	Laborer	Arthritis, chronic, of spine	Alveolar
29	60	♂	Housewife	Arthritis, chronic, of spine	Alveolar
30	50	♂	Housewife	Arthritis, chronic, of spine	Alveolar
31	54	♂	Housewife	Arthritis, chronic, of hip	Teeth not mentioned
32	52	♂	Housewife	Arthritis, chronic, of hip	Upper teeth all gone condition of others not mentioned
33	60	♂	Cook	Arthritis, chronic, of spine	Alveolar
34	53	♂	Laborer	Arthritis, chronic, of knee	Alveolar
35	59	♂	Sollicitor	Arthritis, chronic, of spine	Alveolar
36	61	♂	Fruit picker	Arthritis, chronic, of hip	Teeth not mentioned
37	43	♂	Laborer	Arthritis, chronic, of spine	Alveolar
38	40	♂	Milliner	Arthritis, chronic, of knee	Alveolar
39	43	♂	Housewife	Arthritis, chronic, of spine	Alveolar
40	45	♂	Laborer	Arthritis, chronic, of knee	Alveolar
41	54	♂	Hod carrier	Arthritis, chronic, of spine	Alveolar
42	47	♂	Carpenter	Arthritis, chronic, of spine	Alveolar
43	49	♂		Arthritis, chronic, of spine	Alveolar
44	48	♂	Laborer	Arthritis, chronic, of knee	Alveolar
45	43	♂	Furniture work	Arthritis, chronic, of knee	Teeth poorly kept
46	76	♂	Domestic	Arthritis, chronic, multiple	Alveolar
47	48	♂	Marble polisher	Arthritis, chronic, of shoulder	Alveolar
48	35	♂	Moving picture operator	Arthritis, chronic, of spine	All teeth pulled 3 mos before examination
49	41	♂	Switcheaman	Arthritis, chronic, of spine	Alveolar
50	41	♂	Miner	Arthritis, chronic, of hip	Alveolar
51	37	♂	Laborer	Arthritis, chronic, of spine	Teeth negative
52	64	♂	Laborer	Arthritis, chronic, multiple	Alveolar
53	57	♂	Housework	Arthritis, chronic, of knee	Alveolar
54	48	♂	Laborer	Arthritis, chronic, of spine	Alveolar
55	50	♂	Housewife	Arthritis, chronic, of knee	No note on teeth
56	60	♂	Miner	Arthritis, chronic, of spine	All teeth out
57	50	♂	Laborer	Arthritis, chronic, of spine	Alveolar
58	39	♂	Laborer	Arthritis, chronic, of knee	Alveolar
59	34	♂	Housewife	Arthritis, chronic, of knee	Teeth negative
60	52	♂	Laborer	Arthritis, chronic, of spine	Teeth negative
61	48	♂	Laborer	Arthritis, chronic, of knee	Alveolar
62	44	♂	Housewife	Arthritis, chronic, of ankle	Alveolar
63	40	♂	Iron worker	Arthritis, chronic, of spine	Alveolar
64	55	♂	Dishwasher	Arthritis, chronic, of spine	No note of teeth
65	51	♂	Farmer	Arthritis, chronic, of spine	Teeth not mentioned
66	48	♂	Laborer	Arthritis, chronic, of spine	Alveolar
67	61	♂	Collector	Arthritis, chronic, of hip	Alveolar
68	45	♂	Laborer	Arthritis, chronic, of spine	No note on teeth
69	32	♂	Peddler	Arthritis, chronic, of spine	Alveolar
70	56	♂	Seamstress	Arthritis, chronic, of knee	Alveolar
71	32	♂	Iron worker	Arthritis, chronic, of knee	Alveolar
72	56	♂	Engineer	Arthritis, chronic, of spine	Alveolar
73	34	♂	Laborer	Arthritis, chronic, of spine	Alveolar
74	45	♂	Cook	Arthritis, chronic, of knee	Teeth negative

* In this column, ♂ represents male and ♀ female

CLINICAL PATIENTS—(Continued)

Case	Age	Sex	Occupation	Condition	Infection
75	57	♀	Housework	Arthritis, chronic multiple	"Teeth false"
76	67	♀	Housework	Arthritis, chronic, of knee	"All teeth gone"
77	39	♀	Marine fireman	Arthritis, chronic, of spine	Alveolar
78	40	♂	Metal worker	Arthritis, chronic, of spine	Alveolar
79	62	♂	Laborer	Arthritis, chronic, of knee	Alveolar
80	40	♂	Laborer	Arthritis, chronic, of spine	Alveolar
81	48	♂	Waiter	Arthritis, chronic, of knee	Alveolar
82	67	♀	Housewife	Arthritis, chronic, of spine	Teeth not mentioned
83	59	♂	Laborer	Arthritis, chronic, of hip	Alveolar
84	69	♂	Cook	Arthritis, chronic of shoulder	Alveolar
85	60	♂	Carpenter	Arthritis, chronic, of spine	Alveolar
86	58	♂	Printer	Arthritis, chronic of hips	Alveolar
87	38	♂	Laborer	Arthritis, chronic, of spine	Alveolar
88	59	♀	Housewife	Arthritis, chronic of knee	Alveolar
89	55	♂	Hotel worker	Arthritis, chronic, of spine	Alveolar
90	26	♂	Miner	Arthritis, chronic of knees	Alveolar

Occupation—Nothing suggestive appears in this connection. The occupations are those of the ordinary clinical patients. The occupations of most necessitated hard physical work, but so do those of most clinical patients. This, of course, does not apply to my private patients.

The outstanding fact in the histories is the prevalence of alveolar infection. In seven of the histories the condition of the teeth is not mentioned. In one case, it is stated that "the upper teeth are all gone." The condition of the remainder is not mentioned. In one the history reads "teeth poorly kept." Of the remaining eighty-one, the teeth were negative in four. Even these cases reported negative, in the light of recent experience, must be regarded with suspicion. Case 90 was reported negative, but he had infected tonsils which were removed. On our insistence a second set of roentgenograms was taken, abscesses were discovered, and the correctness of the later diagnosis was established by extraction. Seven patients had lost all their teeth, presumably because of alveolar infection. Seventy patients had alveolar infection. In other words, depending on how one regards the cases in which the teeth had already been extracted, seventy-seven out of eighty-one, or seventy out of seventy-four, patients had alveolar infection. Deduction. The vast majority of patients with this type of arthritis have alveolar infection.

Treatment—The bone and cartilage changes, the actual deformities of the joints are permanent. No treatment except operation will correct them. If they are slight, operation is hardly justifiable, if more extensive, the underlying bone changes are probably so great as to render the results of operation useless or unsatisfactory.

Clinically, we recognize that alveolar infection is the fundamental cause. Therefore, if there is any evidence of infection, the teeth or roots should be extracted. This is the first step in the treatment.

If the pathologic changes are not too great, some improvement will be seen following this. Possibly, if the joints are protected from trauma, they will functionate in a manner approaching normal. Usually, there will be a slight limitation of motion. A light brace may be used to prevent strain. This is rarely necessary.

If the pain continues and is not very severe, dry heat—baking—usually makes the patients fairly comfortable. Other physical therapeutic agents, baths, electricity, etc., do the same. Gentle massage may be given, but forced motion is absolutely contraindicated. It merely damages the joint.

Immobilization is of doubtful efficiency. Passive hyperemia—Bier treatment—often lessens pain.

In severe cases of arthritis of the hip and knee, very rarely in spinal arthritis accompanied by great pain, operation affords the only hope of relief. In the knee, the operation should consist of a resection with the idea of producing a bony ankylosis. When ankylosis occurs the pain subsides.

In the case of the hip, the head of the femur should be removed. Then the trochanter may be thrust into the acetabulum, or the femur may be allowed to dislocate. In either case, the limb should be immobilized in abduction for two or three months. As an alternative for resection, the Albee ankylosing operation may be performed.

In the resection, the ordinary anterior incision is most unsatisfactory, and the removal of the head through it is very difficult. My experience with the Smith-Peterson incision has caused me to be most enthusiastic over it, my intention at present is to employ no other, except occasionally to meet some special indication. If a small part of the proximal border of the acetabulum is chiseled off, the head can be dislocated by an assistant, and sawed or chiseled off very easily.

When a limited section of the spine is involved, an ankylosing operation occasionally may be indicated, but often the spinal joints are ankylosed by Nature, through the means of new bone which forms over the anterior surface of the bodies of the vertebra. Bony ankylosis in the spine proves the one exception to our rule that bony ankylosis is never associated with this type of arthritis.

CONCLUSION

1 The great second type of arthritis has two distinguishing clinical features: (a) bone production (lipping, spurring) at the joint line, and (b) absence (except in spinal involvement) of union between the ends of the bones, either fibrous or bony.

2 Its main pathologic feature is the presence of areas of aseptic necrosis in the bone near the articular surface. This is the primary change. The cartilage changes and the bone production are the result of it.

3 Its primary cause is probably infection in the alveolar processes of the jaws.

4 Infection in the jaws causes only this type of arthritis,⁹ never the first type.

5 The infections which cause the first type, namely, tuberculosis, syphilis, tonsillar and deep urethral infections, never cause this second type. The evidence for 3, 4 and 5 is purely circumstantial. It rests on clinical observation exclusively.

6 Mental emotion and disturbed digestion can only be considered as contributing causes, which change the secretions of the mouth, and make the infection in the jaws more active.

7 Trauma is effective only as straining a joint already mechanically damaged.

8 This is called the senile type of arthritis, merely because elderly people are prone to it. Alveolar infections are more common in the aged. It occurs occasionally in young people whose teeth and jaws are infected.

⁹ That is, Goldthwait's atrophic arthritis, Nichols and Richardson's proliferative arthritis, the English rheumatoid arthritis, etc., which result in fibrous and bony ankylosis.

A COMPARATIVE STUDY OF SODIUM IODID AS AN OPAQUE MEDIUM IN PYELOGRAPHY*

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The purpose of this article is to give the results of a comparative experimental study of the properties of the substances commonly used in pyelography, together with the clinical results obtained with sodium iodid. The use of this substance in roentgenography was first suggested by myself¹ in 1918. A further study confirms certain observations and conclusions made at that time and also makes necessary certain modifications, which will be noted later.

In 1906, Voelcker and Lichtenberg² reported the use of collargol in pyelography, and until recent years colloidal silver preparations have been used almost exclusively for this purpose. It was natural at first to consider colloidal solutions as exceptionally adapted for pyelography. For by such means heavy elements which are relatively opaque to the roentgen ray could be introduced into the kidney pelvis in a comparatively innocuous state. An increasing experience, however, has shown that colloidal silver solutions when used in pyelography may cause necrosis of kidney tissue and produce other harmful effects. This has been commented on by a number of men, and, in fact, the men who first recommended the solution reported that in one patient operated on twenty-four hours after pyelography, some of the silver preparation was seen about the kidney pelvis and ureter. More recently, Braasch and Mann,³ and Burns and Hopkins⁴ have reported further investigations, emphasizing the danger in the use of colloidal silver preparations.

Possibly in this connection the well-known effect of electrolytes on colloidal solutions has not been sufficiently emphasized. It should be understood that many colloidal solutions of silver, at least, are very unstable in the presence of urine which always contains electrolytes in

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1 Cameron, D F. Aqueous Solutions of Potassium and Sodium Iodids as Opaque Mediums in Roentgenography, *J A M A* **70** 754 (March 16) 1918. Cameron, D F, and Grandy, C C. Sodium and Potassium Iodids in Roentgenography, *ibid* **70** 1516 (May 25) 1918.

2 Voelcker and Lichtenberg. Pyelographie (Roentgenographie des Nierenbeckens nach Kollargolfullung), *München med Wehnschr* **53** 105, 1906.

3 Braasch, W F, and Mann, F C. Effects of Retention in the Kidney of Media Employed in Pyelography, *Am J M Sc* **152** 336 (Sept) 1916.

4 Burns and Hopkins. A Comparative Study of the Effects of Thorium and Other Substances on the Renal Parenchyma When Retained, *J Urology* **2** 145, 1918.

appreciable concentrations When urine is added to a colloidal silver solution in a test tube, no immediate reaction is visible, but in the course of a few minutes the solution, which at first was clear, if kept at body temperature, becomes granular in appearance, and gradually a heavy precipitate forms This fact undoubtedly accounts for the frequent finding of, and probably constant deposit of, precipitated silver throughout the kidney parenchyma after pyelography with a colloidal silver medium

In 1913, Kelly and Lewis⁵ recommended a silver iodid emulsion as a suitable medium, and this has proved quite serviceable, though it is apparent that some suitable nonviscid solution would be preferable

In 1915, Burns⁶ introduced the neutral citrate solution of thorium nitrate for this purpose This solution, which Sollmann and Brown⁷ had found to be rather inert pharmacologically, proved to have such great advantages over the other pyelographic mediums in use that it supplanted practically all of them and today is probably used more frequently than any other The fact that this solution has been used so many times with no apparent harmful effect, and that quite good roentgenograms have been obtained is sufficient evidence as to its usefulness This medium differs in principle from others in that it is a solution of a crystalloid and not an emulsion or colloid However, by virtue of this fact, it loses one of the advantages of the colloids, namely, a low osmotic pressure, for it is evident that an ideal medium should have an osmotic pressure within the limits of that of a concentrated urine as a maximum and that of blood as a minimum, and, although the opacity of the thorium solution is generally sufficient, at times a more opaque medium would be preferable Another disadvantage, though not serious, is the fact that thorium nitrate is not always easily obtained, and the standard solution is prepared with some difficulty Again, though the viscosity of the neutral thorium citrate solution is comparatively low, still it is considerably higher than that of simple aqueous solutions of ordinary inorganic salts This is a definite disadvantage, for it delays somewhat the filling of the kidney pelvis and so allows a greater dilution with urine and as a result the definition of the roentgenograms is impaired However, it must be stated that in general the thorium solution is a very satisfactory pyelographic medium, and its use is attended by practically no harmful effects

5 Kelly and Lewis Silver Iodid Emulsion—A New Medium for Skiagraphy of the Urinary Tract Surg, Gynec & Obstet **16** 707, 1913

6 Burns, J. E. Thorium A New Agent in Pyelography, J A M A **64** 2126 (June 26) 1915

7 Sollmann and Brown Pharmacologic Investigations of Thorium, Am J Physiol **18** 426, 1907

In March and May, of 1918, I¹ suggested that certain solutions of the alkali iodids possessed certain advantages over other pyelographic mediums. In particular, it was noted that these substances were non-toxic when absorbed in ordinary amounts, and that their simple aqueous solutions were neutral in reaction, and did not form precipitates with urine. Their opacity to roentgen rays was good, their viscosity low, and they were less expensive than the other solutions in use. These solutions were not hit on by accident, but were selected after a systematic survey of the different compounds of the heavier common elements. Those which were known to be toxic or which formed precipitates with albumin or urine were excluded. Other things being equal, the substance that contained the heaviest elements and that would fulfil these conditions would be most suitable for the reason that its opacity to roentgen rays would be greater than that of solutions of other substances in the same concentration. Solutions of various compounds of bismuth, lead and strontium were tested. It was also attempted to take advantage of the property of citrates and similar organic bases to keep in solution and even render less toxic certain otherwise insoluble and toxic substances. But the results were not promising. Nor did there seem to be any suitable compound of a heavy element and one of the heavier halids, although at first it was thought that one was found in strontium iodid, but this proved to form a slowly appearing precipitate in urine. Nor were the different halid compounds other than those of iodin overlooked accidentally. It was evident that iodin, being by far the heaviest of these, would have the greatest opacity, and so could be used in weaker solutions which would have a comparatively low osmotic pressure. When the alkali iodid solutions were proposed, a 25 per cent aqueous solution of either the sodium or potassium salt was suggested as best suited for pyelography. In the first article, it was stated that the potassium and sodium salts were used interchangeably. In the second, it was again stated that either could be used, but that the sodium salt was to be recommended. In a note⁸ published in June, 1919, certain modifications of these recommendations were given. In particular, it was noted that weaker solutions could be used and that the sodium iodid was much more satisfactory.

In October, 1918, Weld⁹ published an article on the use of sodium bromid in pyelography. In this article, reference was made to neither of my articles on the use of sodium and potassium iodids which appeared in earlier issues of the same journal. And although it was

8 Cameron, D. F. The Use of Iodids in Pyelography, *J. A. M. A.* **72** 1737 (June 14) 1919.

9 Weld, E. H. The Use of Sodium Bromid in Roentgenography, *J. A. M. A.* **71** 1111 (Oct 5) 1918.

definitely stated in the second article that I recommended the use of the sodium salt, in the body of his article, Weld mentioned only the fact that I had recently suggested the use of potassium iodid, and added that its use in a number of cases was attended by serious reactions. Weld recommended a 25 per cent solution of sodium bromid as being less toxic and much less expensive than potassium iodid and of about the same opacity in the same concentration. This statement concerning the relative opacity of these solutions will be shown later to need considerable modification. However, as experimental evidence in support of it, there was given a series of comparative roentgenograms of a number of alkali halids in different dilutions, together with one of a standard thorium solution.

In December, 1918, Burns and Swartz¹⁰ showed that the ordinary dyes used in renal function tests, together with certain other substances, were absorbed quite rapidly from the pelvis of a kidney with an occluded ureter. They determined quantitatively the rate of excretion of these substances by the normal kidney under varying conditions of pressure and hydronephrosis.

In May, 1919, Weld¹¹ reported similar observations when pyelographic mediums were substituted for the dyes. In view of the rapid absorption of substances retained in the kidney pelvis, he emphasized the fact that the pyelographic mediums should be nontoxic. Little difference was found in the effect on renal parenchyma of solutions of sodium bromid and of potassium iodid in the same percentage concentrations. In accordance with the observations of Stockman and Charteris,¹² and many others, Weld found that potassium iodid in concentrated solution given intravenously was very toxic, while a concentrated solution of sodium bromid was quite nontoxic. Since the thorium solution also given intravenously in moderate amounts may at times be toxic, Weld concluded that the 25 per cent sodium bromid solution was the safest and best medium so far recommended for pyelography.

It is possible that this conclusion is correct, but it is quite evident that the work so far reported in support of it is open to serious criticism. In the first place, this conclusion is based partly on the assumption made by Weld in his first article that bromids and iodids in the same concentrations have approximately the same opacity to the roentgen rays. This assumption will be shown later to be entirely erroneous in its application to pyelography. Again, it will be noted that in his comparative tests of toxicity, sodium iodid solutions received

10 Burns and Swartz. Absorption from the Renal Pelvis in Hydronephrosis Due to Permanent and Complete Occlusion of the Ureter, *J Urology* 2: 445, 1918.

11 Weld, E. H. Thesis, University of Minnesota May, 1919.

12 Stockman and Charteris. *Jour Physiol* 26: 277.

no consideration. This is a serious omission for two reasons: first, because sodium iodid when used in pyclography or given intravenously is quite nontoxic in contrast to potassium salts whether bromid or iodid, and the toxicity of different pyclographic mediums given intravenously was one of the factors especially emphasized by Weld; second, we¹³ stated that we recommended the sodium iodid in preference to the potassium salt, and gave it precedence in the title.

Since I first suggested the use of alkali iodids in pyclography, opportunity has been afforded to investigate more thoroughly the toxicity of different solutions and certain of their physicochemical properties which have an important bearing on their usefulness in pyclography. The results of this investigation, together with a report of my personal experience in the use of sodium iodid solutions in pyclography at the University Hospital, Minneapolis, will be given herewith.

EXPERIMENTAL

OPACITY TO ROENTGEN RAYS

A sufficient opacity to roentgen rays and harmlessness to the patient are the two evidently necessary characteristics of pyclographic mediums. In order to make comparable tests of the suitability of the different mediums, it is first necessary to determine what strength solutions have the same opacity under the conditions in which pyclograms are made. If the statement made by several investigators that the opacity of elements to roentgen rays varies directly with their atomic weights were true, the relative opacity problem would be very simple. On the basis of such a relation, it is evident that, with minor corrections, solutions of different substances would be equally opaque if prepared in such a way that the product of the concentration of the dissolved substance by its molecular weight were constant. And it would also follow, with minor corrections for volume, that the opacity of a 25 per cent solution of sodium bromid, for example, would be the same as the opacity of a 25 per cent solution of any other substance. For it is evident that in such solutions the concentration of the molecules of the dissolved substance is inversely proportional to its molecular weight, and that the product of these two quantities would be constant, except for minor corrections. In accord with this, Weld stated that 25 per cent solutions of bromids and iodids had approximately the same opacity, showing certain roentgenograms as evidence.

In contrast to Weld's conclusion, it will be shown later that a 13.5 per cent solution of sodium iodid is slightly more opaque than a 25 per cent solution of sodium bromid when exposed to roentgen rays of the

13 Footnote 1, second reference

same quality as used in pyelography, and with the filter correction which duplicates as nearly as possible the condition under which pyelograms are made

The probable explanation of the differences here noted is simple. In the first place, it will be seen from an inspection of Weld's own illustrations that the observations he reported are incomplete. He states that the illustrations show little or no difference in opacity between the same concentrations of bromids or iodids. It is true they do not show a great difference, but still it is evident that the iodid shadows are the more dense. But there are still several other interesting features. It will be noted that the difference in density of the 12 per cent, 25 per cent and 37 per cent iodid solutions of each substance is comparatively slight. This means that the solutions were not exposed to roentgen rays of sufficient penetration to differentiate these solutions. But in the bromid shadows there is a much better differentiation, especially between the 12 per cent and 25 per cent solutions—which means that these solutions are relatively not so opaque. And, indeed, some of the 12 per cent iodid shadows illustrated appear only slightly less dense than the 25 per cent bromid ones. However, this difference may be brought out much more clearly. For accuracy, several precautions are necessary. The containers for the solutions should not be ordinary unstandardized bottles, the glass of which casts appreciable shadows, but should be thin-walled containers of standardized size made of uniform material of the least possible opacity. For this purpose, from a large shipment, four very thin-walled test tubes were selected whose diameters were greater than 182 mm and less than 187 mm. The opacity of the tubes themselves to the roentgen rays used is very slight and practically constant, so that a minimum constant error is produced. The solutions themselves were made with accuracy from chemically pure materials and distilled water. The molecular as well as percentage concentration is given. The former is by far the more convenient when different dilutions are used. The neutral thorium solution was prepared according to the directions given by Burns. Thorium nitrate free from water of crystallization was used. It should be noted that it is not exactly correct to call it a 15 per cent thorium nitrate solution as is customary, because 15 gm of thorium nitrate in addition to a considerable quantity of sodium citrate and some alkali dissolved in a sufficient amount of water to make 100 cc does not make a 15 per cent solution. It is better designated as a $\frac{5}{16}$ molar solution of thorium nitrate. The exposure to roentgen rays was made under conditions which duplicate as far as possible those under which pyelograms are made. A great error results if rays of low penetration are used. It is well known and easily demonstrated that quite light substances such as hair and gauze, not to mention the lighter

elements like sodium, magnesium and aluminum, for example, will cast quite dense shadows if rays of very low penetration are used, while their shadow is entirely invisible or scarcely visible when the rays used are sufficiently "hard" to penetrate in quantity the human body at the level of the kidney. From this it is evident that in comparative experimental tests of opacity not only must the penetration be as great as that used in pyelography, but also all of the soft rays must be filtered off by suitable means, since they are filtered off in passing through the body. Figure 1 illustrates the relative opacity of the different solutions under the conditions indicated, and is only one illustration chosen from a number made under similar conditions and with the same results. These solutions were also exposed to "softer" rays,

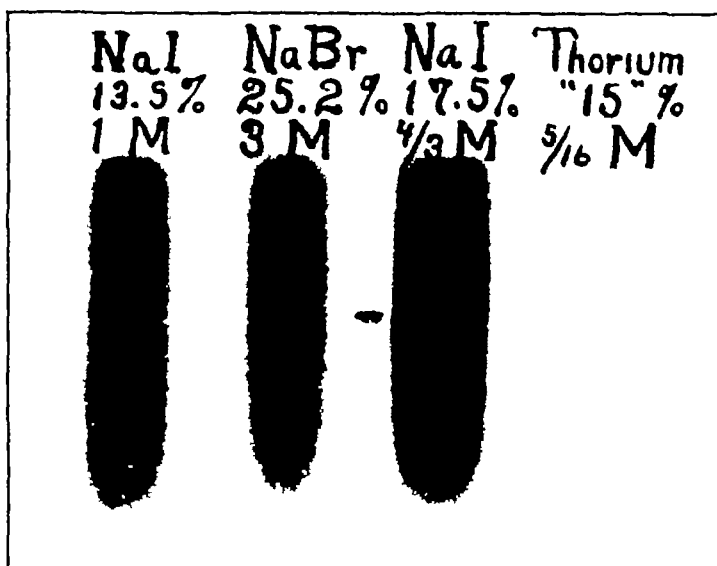


Fig 1—The relative opacity of the solutions indicated under the conditions noted (Coolidge tube, 20 inches distance, 45 inches alternate spark gap, 38 milliamperes current, 5 seconds exposure). A 4 mm aluminum filter was placed in front of, and a similar thickness behind, the tubes, corresponding in general, to the obstruction due to the abdominal walls encountered in practice. The time of exposure, penetration and current are the same as those used generally in pyelography. The thorium shadow on the original negative was relatively denser, and the contrast between the various shadows was less distinct, than in this illustration. Other roentgenograms made under the same conditions except with a 6 inch spark gap and 20 milliamperes current showed the same result except that the iodid shadows were relatively still more intense. The roentgenograms made with 3 inches penetration and less showed denser thorium and bromid shadows.

that is, to rays from a tube with an alternate spark gap of only 3 inches. This has the effect of making the bromid and thorium shadows relatively denser, especially when none of the very soft rays are filtered off by aluminum plates.

From several series of experiments, of which only one plate is reproduced, it may be stated definitely that with conditions for pyelography duplicated, the molar (13.5 per cent) solution of sodium iodid has the same or even a trifle greater opacity than a 3 molar (25.2 per cent) solution of sodium bromid, and further, that these two solutions have a definitely greater opacity than the standard neutral thorium citrate solution.

Aside from its bearing on pyelography, this result in the case of iodids and bromids is of interest in that it agrees closely with the results obtained by various physicists who have investigated the opacity of elements to roentgen rays by different and more exact methods. The most convenient summary of results of experiments in this line will be found in two comparatively recent publications by Auren¹⁴. Certain of his results, with which my own are in accord, are of particular interest. He states that iodin with two or three other elements, not including bromin, possesses the property of selective absorption of roentgen rays especially marked with the rays of high penetration. In other words, iodin and the compounds of iodin are much more opaque to the roentgen rays than would be expected from the known properties of this element and its position in the periodic table. Auren gives the "roentgen-ray atomic absorption coefficient" of practically all of the ordinary elements, and from this table the opacity of $\text{a}\frac{1}{2}$ concentration of the commoner substances can be calculated. A few of these values of particular interest in this connection are transcribed in Table 1. The molecular absorption coefficient of water is arbitrarily taken as unity.

The values given in Table 1 represent the average opacity of the elements to comparatively soft rays. Of particular interest are the values for different wave lengths. These values, which show the selective absorption property of iodin, are given in Table 2.

The "hardness" of the rays (which varies inversely with their wave lengths) is represented by the thickness of the aluminum filter indicated above the absorption coefficient values. The penetration used in pyelography corresponds to that represented in the third and fourth columns. The values shown in Table 2 are seen to agree almost exactly with those obtained by myself as shown in Figure 1. That is, one iodin atom has the opacity of three bromin atoms to waves of this length. It should be added that the plates that I exposed to softer rays showed a relatively greater opacity of the bromid and thorium solutions, which agree closely with the values shown in column 1. When soft rays are used, the shadows of the thorium and bromid solutions are more dense than the molar iodid solution. But it is very

¹⁴ Auren, T. E. Notes on the Absorption of X-Rays. *Phil. Mag.* Series 6 **33**: 471. The Absorption of X-Rays. *ibid.* **37**: 165.

important to note that such rays are much softer than those used in pyclography, and the absorption values so obtained are in no way applicable in pyclography

Auren and most physicists in their work measure the intensity of transmitted roentgen rays by the degree of ionization produced in a protected chamber behind the absorbing medium. This method of measuring intensity is more accurate than the photographic method, but in testing pyclographic mediums the photographic method is of relatively greater value. However, from the work of Barkla and

TABLE 1—ROENTGEN-RAY ATOMIC ABSORPTION COEFFICIENT OF VARIOUS ELEMENTS

Element	Atomic Weight	Atomic Number	Absorption Coefficient
Hydrogen	1	1	0.05
Oxygen	16	8	0.9
Sodium	23	11	1.9
Aluminum	27	13	2.4
Potassium	39	19	11.1
Calcium	40	20	14.4
Bromine	80	35	154.0
Silver	108	47	300.0
Iodine	127	53	315.0
Lead	207	82	569.0
Thorium	232		(1 000 approximately, by interpolation, D. F. C.)
Uranium	239	92	1 123

TABLE 2—VALUES OF DIFFERENT WAVE LENGTHS

Element	Atomic Weight	Atomic Number	Absorption Coefficient			
			I 1.2 mm Aluminum Filter	II 2.5 mm Aluminum Filter	III 5 mm Aluminum Filter	IV 10 mm Aluminum Filter
Bromine	80	35	152.5	137.7	119.0	100.0
Iodine	126	53	220.0	332.0	356.0	366.0

Martyn¹⁵ and others, it is known that the photographic effect of rays is rather variable. Soft rays produce relatively too great, and hard rays relatively too little effect on the photographic plate. Irregularities in the photographic film, secondary radiation induced and exposure to heterogeneous rays are also disturbing factors. Under similar conditions, however, the results obtained by the two methods are not widely divergent. And an examination of the results makes evident the fact that no simple relation exists between either the atomic weight or the atomic number of an element and its absorption coefficient. Bragg and Pierce,¹⁶ in an investigation of this relationship, came to the con-

15 Barkla and Martyn. Photographic Effect of X-Rays, Phil. Mag., Series 6, 25 296

16 Bragg and Pierce. Absorption Coefficients of X-Rays, Phil. Mag., Series 6, 28 626

clusion that the atomic absorption coefficient of an element varied with the fourth power of the atomic number, but, as yet, there is no generally accepted formula connecting these values. It is important that these facts should be emphasized in medical literature for, through ignorance of them, a number of incorrect statements have been made in recent medical publications involving the question of the relative opacity of pyelographic mediums. It will be seen that among the lighter elements the roentgen-ray opacity increases relatively slowly with atomic weight, while with the heavy elements this increase is much more marked.

In general, for ordinary pyelographic work, the molar (13.5 per cent solution of sodium iodid and the 3 molar [25.2 per cent]) solution of sodium bromid have the same opacity and the opacity of the standard thorium solution is definitely less, corresponding approximately to that of a 10 per cent sodium iodid solution. And from the data given, the important fact is obvious that with increasing roentgen-ray penetration the relative opacity of the iodid solution increases and the opacity of the bromid and thorium solutions decreases. Moreover, this difference is not slight but is very marked, and constitutes one of the real advantages of the iodid solution in pyelography.

TOXICITY

In contrast to the comparative ease and accuracy with which the opacity of these solutions can be determined, the determination of their relative toxicity is less satisfactory, especially since the toxic effects of none of them are marked. But it is evident that in order to obtain comparable results, solutions of the same opacity must be used. It is also evident that the toxicity of these solutions may be due either to the specific action of the substances in solution on different living tissues, or to the effect of the hypertonic solution in which the substances are carried, or to a combination of these two effects.

The effect of these solutions on the kidney itself is naturally the first to be determined. For this test, normal and hydronephrotic dog kidneys were used, and both functional and anatomic changes were determined when possible.

RESULTS OF EXPERIMENTS

EXPERIMENT 1—A cannula was inserted into each ureter of a dog which was kept under ether anesthesia. One cc of phenolsulphonephthalein was given intravenously. Diuresis was stimulated by giving Ringer's solution and hypertonic glucose solution¹⁷ intravenously. In twenty-five minutes the urine excreted

¹⁷ Woodratt, R. T., Sinsum, W. D. and Wilder, R. M. Prolonged and Accurately Timed Intravenous Injections of Sugar. *J. A. M. A.* 65:2067 (Dec 11) 1915.

by the right kidney contained 32 per cent of the dye, the left 35 per cent. Thereupon the right kidney pelvis was filled with a molar solution of sodium iodid which was kept under a pressure head of from 34 to 32 inches of the solution for twenty minutes. The secretory pressure of the kidney was approximately 32 inches, since the height of the fluid fell gradually from 34 inches to that level, where it remained quite constant. The blood pressure was recorded continuously throughout the experiment and was not affected materially at any time as a result of the intravenous injections or distention of the kidney pelvis. The urine collected during this time at five minute intervals from the left kidney showed no iodid when tested with chloroform, acetic acid and hydrogen peroxid.

After the expiration of twenty minutes the pressure of the sodium iodid solution on the right kidney pelvis was discontinued and a rest of five minutes

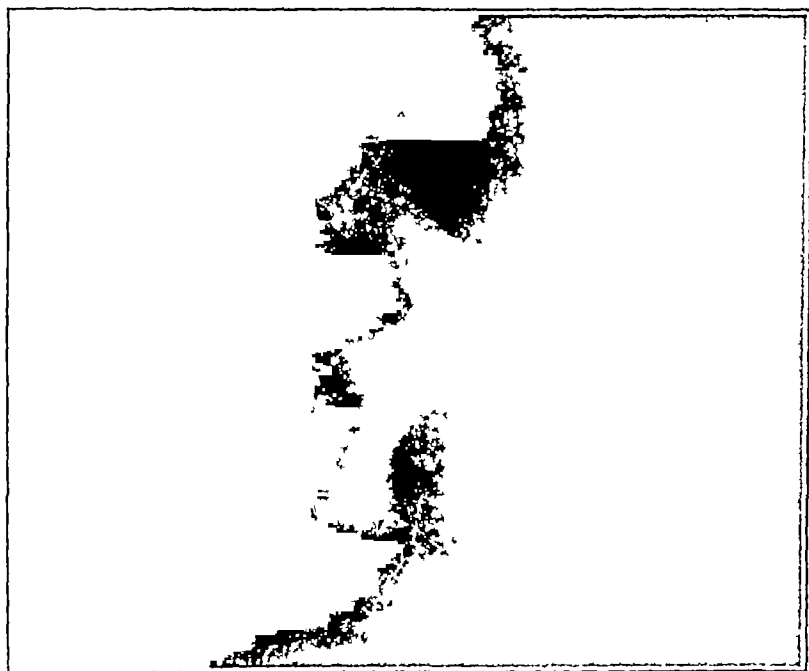


Fig 2—Right pyelogram with molar (135 per cent) solution of sodium iodid, capacity of pelvis, 10 cc. Patient was an unusually heavy man.

allowed. One cc of standard phenolsulphonephthalein solution was again given intravenously, and the urines were collected for fifteen minutes. In this period, the right kidney excreted 26 per cent and the left, 28 per cent.

The right kidney pelvis was then kept distended for fifteen minutes with a 3 molar (25.2 per cent) solution of sodium bromid under a head of from 36 to 34 inches, the secretory pressure of the kidney apparently having risen somewhat for the specific gravity of the bromid solution is appreciably higher than that of the iodid. At the end of this period a functional test was again made, the right kidney excreting 27 per cent, and the left, 31 per cent, of the dye in fifteen minutes.

EXPERIMENT 2—Experiment 1 was in part repeated on a second dog, but unfortunately the specimens of the preliminary functional test were lost. After

the right kidney pelvis had been kept distended for twenty-five minutes with a molar sodium iodid solution at secretory pressure, the functional test was repeated, the right kidney excreting 40 per cent, and the left 40 per cent of phenolsulphonephthalein

At the conclusion of these experiments, the kidneys were removed and examined for gross and microscopic changes, but none were noted. In these experiments no immediate diminution in renal function, as indicated by the phenolsulphonephthalein test, was observed after the kidney pelvis was kept distended for from twenty to twenty-five minutes with molar sodium iodid, or fifteen minutes with 3 molar sodium bromid solution at the secretory pressure of the kidney. It will be noted that both the time of the distention and the pressure are several times as great as occurs in practice when pyelograms are made, i e, if the medium is injected by the gravity method

EXPERIMENT 3—To duplicate, after a fashion, the situation resulting when the pvelographic medium is introduced into a kidney pelvis which fails to empty itself immediately, the right kidney pelvis in each of seven dogs was filled with 4/3 molar (17.5 per cent.) sodium iodid solution under 12 inches pressure. The amount of solution introduced averaged about 2 cc. The ureter was then doubly ligated and divided. The right ureter in an eighth dog was doubly ligated and divided to serve as a control. All of the dogs survived until killed, and with no apparent harmful effects as far as general health was concerned. The first specimen of voided urine from the injected dogs showed a strongly positive test for iodin in each case. The test remained positive for at least twenty-four hours, no test being made at later times. After the injections, the animals were killed at periods varying from forty-five minutes to seventy-five days. The kidneys were removed and the contents of the right pelvis tested for the presence of iodids. The test for iodids in the pelvic contents of the ligated kidney was negative in the five dogs that were allowed to live two hours or over after injections. Iodid was present in the two specimens obtained from dogs killed in forty-five minutes and one and one-half hours, respectively. The rate of absorption was not thoroughly investigated, but in instances in which there was good diuresis and when the iodid solution had been introduced into the right kidney pelvis with a syringe and probably under higher pressure than usual, iodid appeared in the urine excreted by the left kidney five minutes later. At other times however, when the right kidney pelvis was kept distended with the iodid solution under an even pressure up to the secretory pressure, no iodid was found in the urine from the left kidney excreted in from fifteen to twenty minutes after the injection.

The absorption from a hydronephrotic kidney was also tested. The animal, whose right ureter had been occluded for seventy-five days, was found to have a large palpable tumor appearing in the right upper part of the abdomen. This was found to be a hydronephrotic kidney sac containing 450 cc of fluid under 9 inches of pressure—about one third or one fourth of the normal secretory pressure found. The fluid was evacuated through the ureter. Following intravenous injection of saline and hypertonic glucose solution the left kidney showed a good diuresis but no fluid was excreted by the right. At this time 50 cc of 4/3 molar (17.5 per cent.) sodium iodid solution was introduced into the hydronephrotic sac which was thereby only slightly distended. Urine collected from the left kidney in ten, fifteen and twenty minutes showed iodid in rapidly increasing amounts and in much greater concentration than found previously when the iodid solution was introduced into normal kidney pelvis.

COMMENT

I do not now intend to advocate the use of potassium iodid solution for pyelography, but in view of the rapidity of absorption of substances from the kidney pelvis and the well-known toxicity of potassium

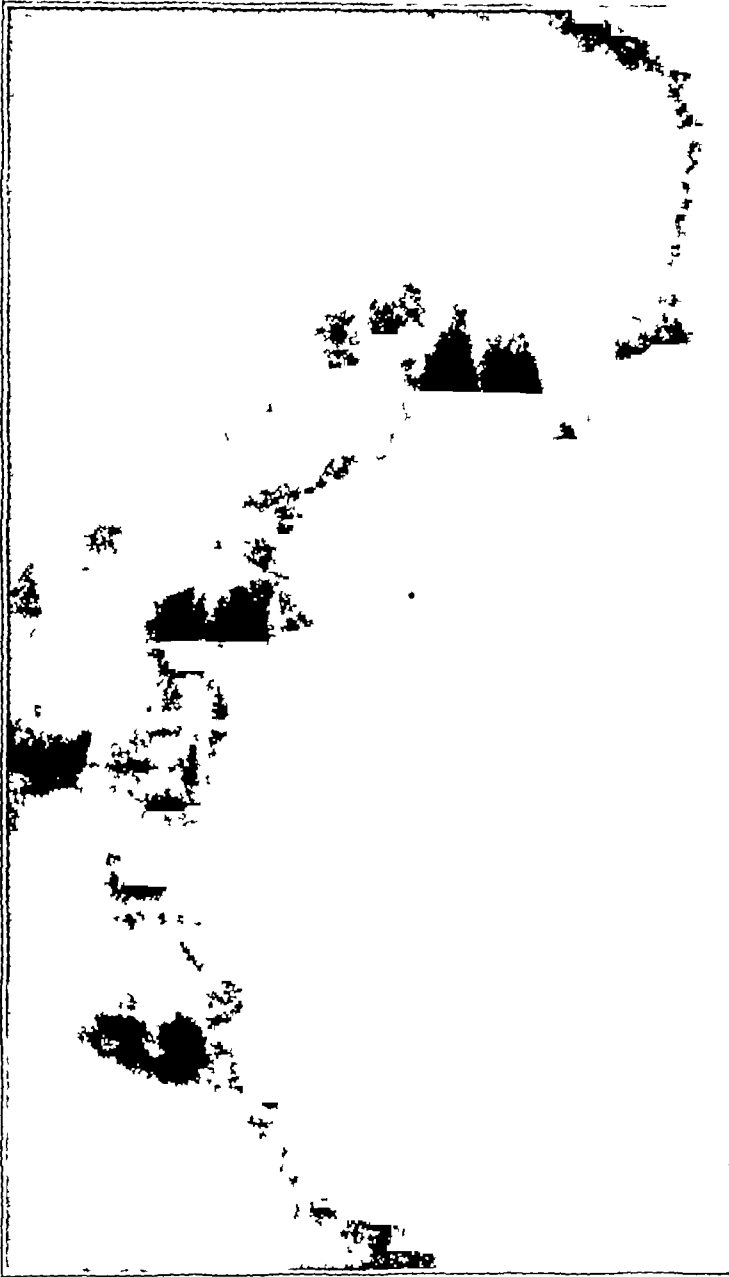


Fig 3 (Miss H) —Left pyelogram with four-thirds (175 per cent) solution of sodium iodid. Distinctness of minor calices may be noted, and their shape compared with that in Figure 4

salts when given intravenously, the effect of the introduction of strong potassium iodid solution into the hydronephrotic sac was tested

Thirty c c of a 25 per cent solution of potassium iodid was introduced into the hydronephrotic sac which had been evacuated of all contents. A blood pressure tracing taken for the following ten minutes showed no circulatory changes. Likewise, no toxic effects of any kind were noted when a normal kidney pelvis was kept distended with a 25 per cent solution of potassium iodid under 34 inches of pressure for a period of twenty minutes. As a matter of fact, in order that toxic



Fig 4 (Miss H) —Right pyelogram with 17.5 per cent sodium iodid solution. History of repeated right-sided kidney colic.

effects should be produced, the absorption of potassium iodid from the kidney pelvis would have to be more rapid than from the gastrointestinal tract.

Pathologically the kidneys whose pelvis had been injected and whose ureters had been ligated showed very marked changes which varied in degree with the time elapsing after the ureteral occlusion, and showed all stages of hydronephrosis. But any changes which might have been due to the presence of sodium iodid were completely

overshadowed by the effects of occluding the ureter, since the changes following occlusion of the ureter alone could not be distinguished from those in which sodium iodid solution had also been injected

This series of experiments shows that animals may live in apparently good health after the function of one of two normal kidneys has been lost by occlusion of its ureter, and that a $\frac{4}{3}$ molar (17.5 per

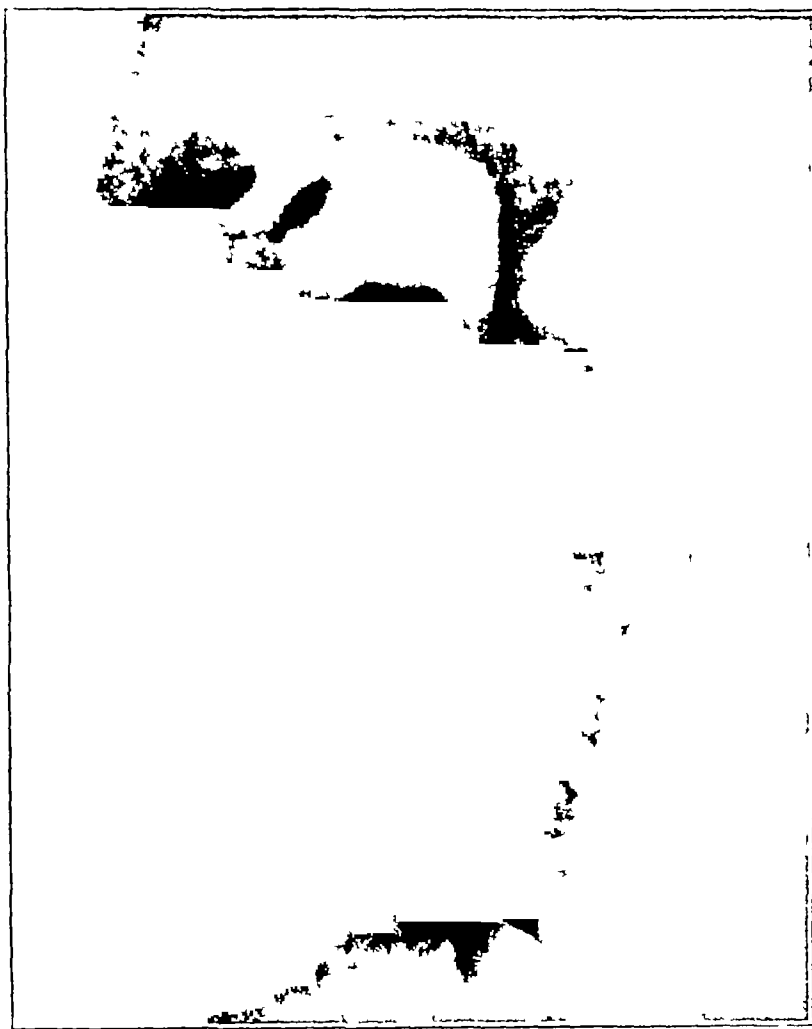


Fig 5 (Miss C) —Right pyelogram with 17.5 per cent sodium iodid solution, thin patient

cent) solution of sodium iodid introduced into the pelvis of the kidney whose ureter has been occluded is absorbed, as a rule, in about two hours and causes no apparent harm, similar results being noted by Burns and Weld when other solutions were used. Rough quantitative tests also showed in the one case investigated that the total amount of sodium iodid absorbed in a given time from a large hydronephrotic sac filled with the iodid solution was much greater than the amount

absorbed in the same time from the pelvis of a normal kidney whose ureter had been occluded and which had been filled with iodid solution of the same strength. The absorption of potassium iodid from the hydronephrotic sac containing 30 c c of a 25 per cent solution was not sufficiently rapid to cause apparent circulatory changes, nor were there any effects noted when a normal kidney pelvis was kept distended with a 25 per cent potassium iodid solution under 34 inches of pressure.

TOXICITY OF MEDIUMS GIVEN INTRAVENOUSLY

The true tests of toxicity of pyelographic mediums should be made by determining the effects of these solutions when introduced into normal and diseased kidneys or ureters. However, it adds somewhat to the factor of safety if these solutions are not toxic when introduced directly into the blood stream in such amounts and concentrations as might occur from absorption from the kidney pelvis or might result from the accidental use of too great pressure in injection of the solution into the pelvis.

In the first experiment, a dog weighing 34 pounds was used. The intravenous injection of 5 c c of a $4/3$ molar sodium iodid solution in thirty seconds caused no changes in the blood pressure curve. The subsequent injection under the same condition of the same amount of 3 molar sodium bromid and of the standard thorium solution was likewise without effect. The injection of 5 c c of molar potassium iodid solution caused a definite fall in blood pressure with gradual recovery. The experiment was repeated on the same dog, 16 c c of each solution being given in forty-five seconds. The injection of the $4/3$ molar sodium iodid and of the 3 molar sodium bromid was without effect. Following the injection of the thorium solution, a very definite fall in blood pressure occurred, with gradual recovery. The dog died in fifteen seconds after the beginning of the injection of the molar potassium iodid. In other experiments, the amount of bromid and iodid solution given was considerably increased. No marked effects were caused when 50 c c of a 25 per cent sodium iodid solution were injected in eight minutes in a 25-pound dog, the blood pressure curve rising slowly. The same amount of a 25 per cent sodium bromid solution was given in ten minutes in a 30-pound dog, without apparent effect, thus confirming the result obtained by Weld. This dog died following the injection of 2 c c of 25 per cent potassium bromid solution.

From this series of experiments, it is seen that 25 per cent solutions of sodium iodid and sodium bromid given intravenously in amounts up to 50 c c in 30-pound dogs produce very little immediate effect. It will be noted that this iodid solution is of nearly twice the concentration

which is recommended for pyelography. The standard thorium solution is relatively nontoxic, but definitely more toxic when given intravenously than either the sodium iodid or sodium bromid solutions. Potassium salts, as has long been known, are very toxic when given

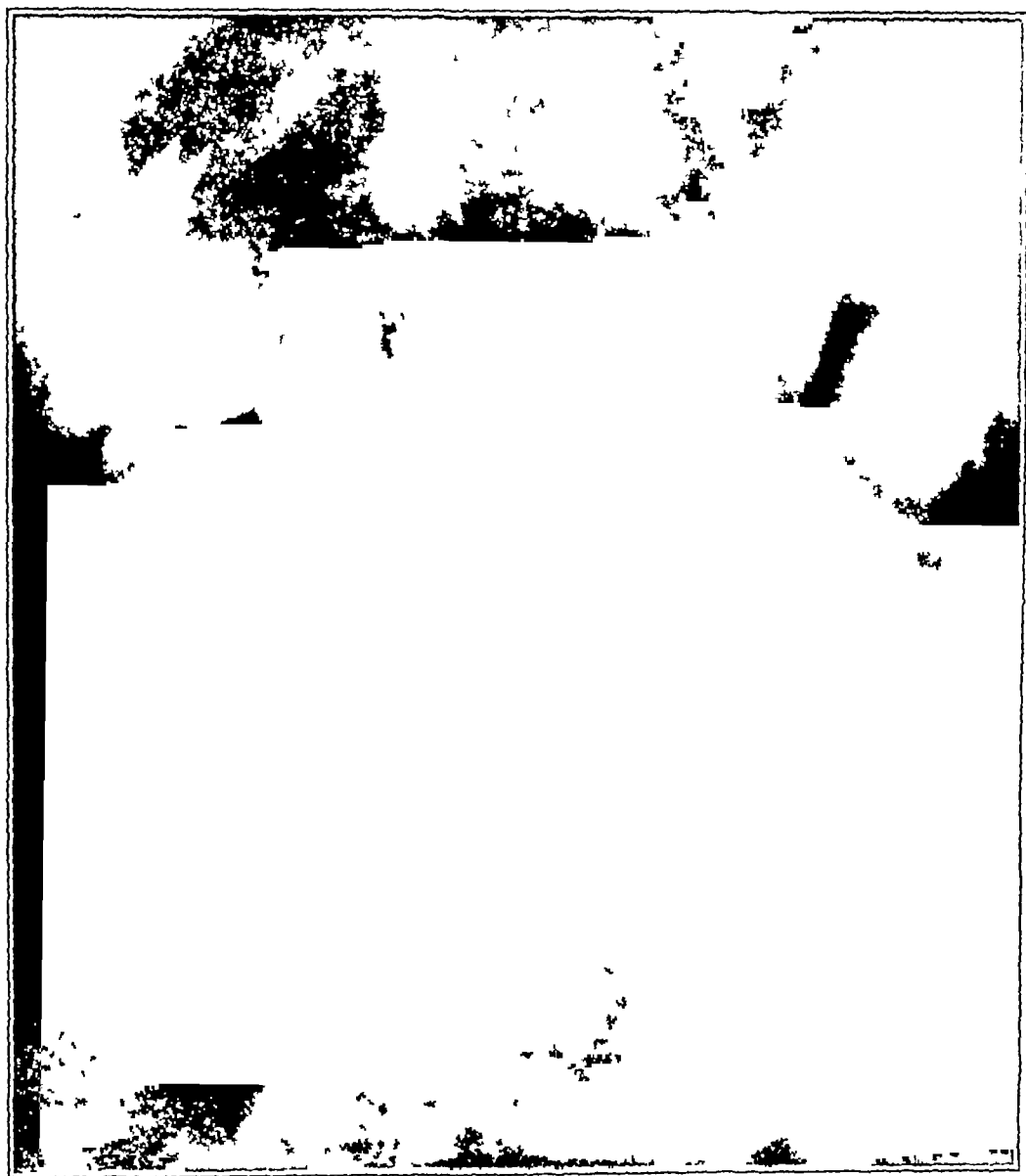


Fig. 6 (Mrs. R.)—Triple pyelogram with 17.5 per cent sodium iodid, thin patient. Fused kidney with two pelves and ureters on the left. The condition was first diagnosed and the three ureters catheterized by Dr. F. R. Wright.

intravenously. It should be noted that in his comparative toxicity tests with sodium bromid, Weld used potassium iodid throughout instead of sodium iodid, and the marked toxicity of potassium iodid intrave-

nously, which he commented on and on which he based his serious objection to the use in general of iodids in pyelography, is due to the potassium ion

It may be noted in passing that intraperitoneal injection of 20 c c of molar sodium iodid, 3 molar sodium bromid and standard thorium solution showed no constant differences in their effects produced within the two hours following the injection

In general, the pure sodium iodid and bromid solutions were found to be strikingly nontoxic. It is probable, however, that these and the potassium salt solution, if desired, could be made still less toxic by the addition of small amounts, in correct proportion, of other salts, e g, of calcium or magnesium, which Jacques Loeb,¹⁸ Mathews¹⁹ and others have shown to have a marked antagonistic effect on the toxicity of potassium and sodium ions. On the whole, the experiments made show that there is no marked difference in specific toxicity of iodids and bromids, the cation being the same, when solutions of the same percentage concentration are used. Of course, it must be noted that a 25 per cent iodid solution has a much lower osmotic pressure than a similar 25 per cent bromid solution, also that a 25 per cent iodid solution is much more concentrated than that recommended for pyelography. Very detailed experiments in the toxicity of different anions and cations in relation to their solution tension and its relation to osmotic pressure are reported by Mathews²⁰. The iodid ion is considered only slightly more toxic than the bromid ion.

OSMOTIC PRESSURE

The other possible cause of toxic effects resulting from the use of these solutions is their osmotic pressure. Of the several ways in which osmotic pressure of solutions may be determined, the most feasible for the solutions concerned is the freezing point method. Very accurate results may be obtained. The osmotic pressure of a solution is directly proportional to the depression of the freezing point below that of the pure solvent. The solutions tested were those used in the experimental work already reported. The depression of the freezing point of the iodid and thorium solutions noted in Table 3 is twice the value found for the solutions diluted with an equal volume of distilled water. This involves a slight but negligible error.

18 Loeb, Jacques. *The Dynamics of Living Matter*, New York, Columbia University Press, 1906.

19 Mathews, A. P. The Toxic and Antitoxic Action of Salts, *Am J Physiol* **12** 419, 1904-1905.

20 Mathews, A. P. The Nature of Chemical and Electrical Stimulation, *Am J Physiol* **11** 455, 1904, The Relation Between the Solution Tension, Atomic Volume and the Physiological Action of the Elements, *ibid* **10** 290, 1904.

According to Jones and Bassett,²¹ the freezing point of solutions of sodium iodid and sodium bromid of the same molecular concentration is approximately the same and the actual lowering is greater than the theoretical, owing to the formation of hydrates. For comparison, the usual values for the freezing point of blood and of a concentrated urine may be taken as -0.56°C and -2.70°C , respectively. The value for a very concentrated urine is considerably higher.

It is evident from these data that the molar solution of sodium iodid has a somewhat higher osmotic pressure than a concentrated urine, but in this respect comes much nearer than any of the other solutions to fulfilling the ideal requirements. It will be noted that the bromid solution has an osmotic pressure more than three times that of the iodid. This fact is of considerable importance, for it is well known that tissues are injured by being exposed to hypertonic solutions.

TABLE 3—FREEZING POINTS OF IODID AND THORIUM SOLUTIONS*

Solution	Freezing Point Degrees C
Sodium iodid, molar (15.7%)	-3.78
Neutral thorium standard, Prep. A	-3.52
Neutral thorium standard, Prep. B	-3.61
Sodium bromid, 3 molar (21.2%)	-13.47

* The value for 3 molar sodium bromid given is calculated from the data given by Jones and Getman (Ueber das Vorhandensein von Hydraten in konzentrierte wässerliche Lösungen von Elektrolyten, *Zeitschr. f. physik. Chem.* 19: 25).

IRRITATION

The pain or discomfort which might be caused by the action of various solutions on sensory nerves of the kidney pelvis and ureter is somewhat difficult to determine, owing to the fact that the pain may be caused by one or more of several other factors, such as the catheterization alone or the overdistention of the kidney pelvis. It is well known that the pain during and after cystoscopy and ureteral catheterization alone may be quite severe. Again, the intrapelvic pressure need not be higher than the secretory pressure of the kidney under certain circumstances to cause colic. Therefore, pain during or following pyelography must not be attributed to the nature of the pyelographic medium unless the other causes are definitely known to be absent. Also, increasing experience shows that overdistention of the kidney pelvis, even though the gravity method is used, is a frequent cause of discomfort.

²¹ Jones and Bassett. The Approximate Composition of the Hydrates Formed by Certain Electrolytes in Aqueous Solutions at Different Concentrations, *Am. Chem. J.* 33: 534, 1905.

The relative sensory stimulation produced by the various pyelographic mediums on tissue supplied with special sensory nerves can be easily determined. Very definite and striking results are obtained when the tongue is immersed in the various mediums. The standard



Fig 7 (Mrs. R.) —Upper pelvis on left filled with 19 per cent sodium iodid solution. Shadow of two stones and lower pole of the kidney distinctly seen.

neutral thorium solution which has a high sodium citrate content in addition to the thorium nitrate is surprisingly mild to the tongue and almost tasteless. A molar solution of sodium iodid has a distinctly

saline taste and causes no further apparent stimulation, even when the tongue is kept immersed in it for some time. The 3 molar sodium bromid solution, which Weld advocated as being quite bland, causes a definitely more intense stimulation on the tongue, at least, than that produced by the sodium iodid solution. It was found, however, that solutions of potassium salts were always distinctly more irritating to the tongue than solutions of the same concentration of sodium salts. This fact was overlooked in testing the stronger solutions recommended in my first articles, and now constitutes one of the main objections to the use of either potassium iodid or potassium bromid solutions. The calcium and strontium salts which also were tested were more or less irritating to the tongue. It is obvious, of course, that the kidney pelvis, which is insensible to presence of urine is not nearly so sensitive to chemical stimulation as the tongue.

VISCOSITY

The ease with which these various solutions flow through small catheters and spread and diffuse into the smaller calices of the kidney pelvis depends primarily on their viscosity.

TABLE 4—RELATIVE VISCOSITY OF VARIOUS SOLUTIONS

Solution	Viscosity
Distilled water	28.0
Molar sodium iodid	9.0
3 molar sodium bromid	31.5
Neutral thorium	50.0

The viscosity of the solutions was determined by the viscometer used for blood work. The figures given in Table 4 represent the time in seconds required for the solution tested to flow from the graduated chamber through the capillary exit. These values represent the relative viscosity of the solutions noted. The whole apparatus and solution were immersed in a water bath kept at body temperature.

It is obvious from these results that distilled water and the iodid solution have approximately the same viscosity. The bromid solution shows a slight increase. The thorium solution is definitely more viscid. This is not so serious, but, nevertheless, is a definite handicap when the easy and rapid flow and diffusion of the solution under a minimum pressure is desired. From the figures given, it is seen that a given quantity of the iodid solution would flow into the kidney pelvis in much less time than would be required for the same quantity of the thorium solution, the pressure head being the same. In this connection, it must be remembered that the kidney is secreting urine continuously, and the concentration of the pyelographic medium in the pelvis is lowered in proportion to the time consumed in filling it. And thus the opacity o

the standard thorium solution which was determined experimentally in the test tube is considerably diminished in practice, through relatively greater dilution with urine in the kidney pelvis

CLINICAL RESULTS

To Dr A C Strachauer I am indebted for the opportunity of putting to practical use solutions of sodium iodid in pyelography, the work being carried out on the surgical service at the University Hospital Minneapolis

The results given here are based entirely on my experience in using for pyelography sodium iodid in concentrations varying from 20 per cent to 13.5 per cent in strength. In all, twenty-two pyelograms and ureterograms were made. At the beginning of the work the stronger solutions were used, but it was soon seen that the results were very good with weaker solutions, and lately the 13.5 per cent solution has been used altogether. The results with it have been so satisfactory, even when it was put to a severe test in unusually heavy patients, that it seems probable that no stronger solution need ever be used, and in thin patients still weaker ones would suffice. It will be noted that a molar solution of sodium iodid is formed when 15 gm of the salt is dissolved in a sufficient amount of water to make 100 cc, and this will be found to contain 13.5 per cent sodium iodid by weight. Likewise, the 17.5 per cent and $4/3$ molar solutions are identical and are formed by dissolving 20 gm of salt in a sufficient amount of water to make 100 cc.

The pyelograms obtained were uniformly good. They were all made with the ordinary gas tube, the alternate spark gap varying from 4 to $4\frac{1}{2}$ inches. For the excellent roentgenographic work displayed in making the pyelograms as well as in the investigation of the relative opacity of numerous solutions, credit is due Miss Bagamill of the University Hospital. The average quality of the pyelograms is shown in the accompanying illustrations, which do not represent in any way exceptional results, for the pyelograms illustrated, with the two exceptions noted, were obtained with patients well above the average in weight. The solution was always injected by the gravity method, the exposure being made while the kidney pelvis was being filled. The apparatus described by Thomas²² is well suited for this purpose. In this connection it is well to emphasize the point made by several men that the technical results are very much better if the exposure is made while the kidney pelvis is still being filled. This point must not be overlooked if good results are desired. On two occasions, I attempted to make a double pyelogram, using a buret with a single catheter

²² Thomas G J. An Apparatus for the Injection and Lavage of the Pelves of the Kidneys and the Ureters, *J A M A* 60 184 (Jan 18) 1913

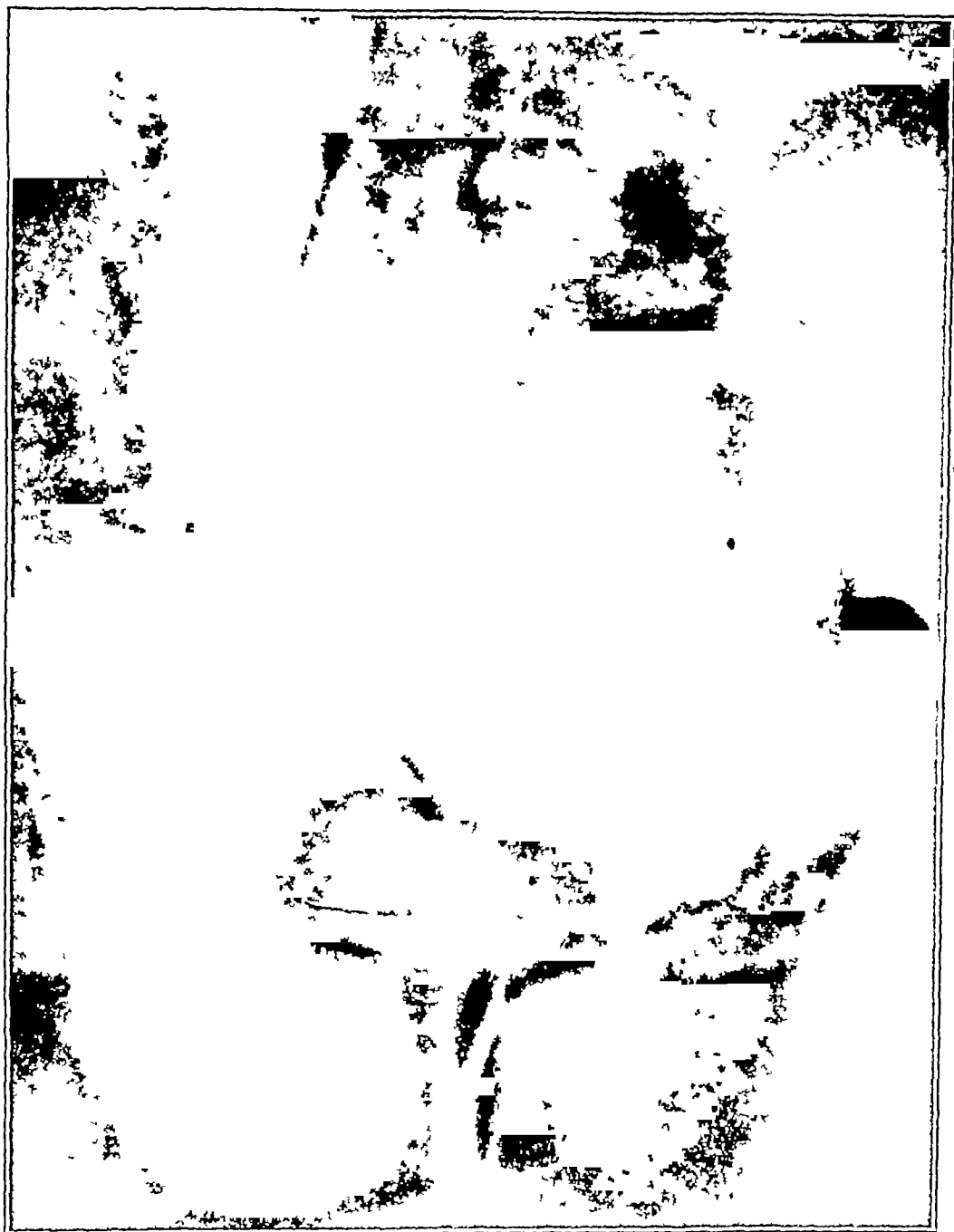


Fig 8 (Mrs R) —Left lower ureterogram. Irregular shadows, shown near the bladder in the original roentgenogram, are localized by this ureterogram. The patient subsequently passed four small stones spontaneously. It will be noted that the upper pelvis of this kidney and its ureter were free from stones. A 17.5 per cent sodium iodid solution was used.

needle After the first pelvis was filled, the catheter was occluded by a small wooden cork and the needle transferred to the other catheter In each instance, the technical result was poor on the side first filled The amount of solution introduced into the kidney pelvis varied from 4 to 10 c c, the least amount introduced (4 c c) of the 4/3 molar solution represented the capacity of a polycystic kidney pelvis, and an excellent pyelogram was obtained In no case in my rather limited experience with the molar solution has a poor pyelogram resulted as the result of insufficient opacity of the medium But if experience should show that a more opaque medium is desirable at times, it should be remembered that the 4/3 molar (17.5 per cent) solution of sodium iodid may be used with perfect safety, and that it is much more opaque than either the 25 per cent bromid or standard thorium solution

To determine the amount of discomfort or pain produced, the patients were carefully observed and questioned while the pyelograms were being made and afterward A reasonable allowance was made for the distress occurring after cystoscopy and ureteral catheterization alone The results may be thus summarized In no instance was there any increase whatever in discomfort noted or complained of while the first 4 or 5 c c of any of the iodid solutions used were being introduced into the kidney pelvis Several patients, on whom differential functional tests had just been made, were unable to distinguish any new sensations whatever, either during or subsequent to the filling of the pelvis Figure 2 is a pyelogram of such a patient, in whose kidney pelvis 10 c c of the molar solution was introduced A few of the patients began to have increasing distress when the injection was continued after 4 or 5 c c of solution had been introduced In view of the absolutely painless procedure in a number of cases, I am convinced that the distress in these instances was caused entirely by overdistention of the kidney pelvis, it being evident that only a small amount of solution might cause an overdistention of a pelvis which, at the same time, was being rapidly filled with urine It was soon learned, as has been especially emphasized by Braasch,²³ that the injection should not be carried so far as to produce pain, thus far, the small amount of solution injected painlessly in such cases has been sufficient to outline the pelvis, though it is evident this might be unsatisfactory if one were dealing with a hydronephrosis During the twenty-four hours after pyelography, some of the patients have complained of distress, occasionally quite severe, felt in the kidney region and along the ureters, but this trouble, except in those who had had an evident overdistention of the kidney pelvis, could be considered no more severe than that occasionally produced by ureteral catheterization alone On the whole,

23 Braasch, W F Pyelography, Philadelphia, W B Saunders Company

it may be stated that no increased discomfort is caused by the introduction of a molar, or $4/3$ molar, solution of sodium iodid into the human kidney pelvis, provided no overdistention is produced.

It was also considered of interest to determine what changes, if any, are produced on the function of the human kidney, the pelvis of which has been filled with the iodid solution. It will be recalled that this procedure had no effect on the kidney function in the dog. In Table 5, the total renal function before and after double pyelography is given. The total functional change after single pyelography is not given, as it would be of little significance, since an appreciable damage to one of two good kidneys might produce little or no change in total function.

From these results it is evident that the use of sodium iodid in pyelography causes no diminution of renal function demonstrable by the ordinary functional tests.

TABLE 5—TOTAL RENAL FUNCTION BEFORE AND AFTER DOUBLE PYELOGRAPHY

Patient	Original Phenolsulphon- phthalein Excretion per Cent	Procedure	Solution Used per Cent	Phenol sulphon- phthalein Excretion Afterward, per Cent
Mr. S.	45	2 double pyelograms	17.5 13.5	43
Mrs. R.		2 triple pyelograms	17.5	64
Miss Y.	75	Double pyelogram	17.5	72
Miss D.	65	Double pyelogram	17.5	71
Mrs. W.	Blood urea nitrogen 12 mg Creatinin 1 mg	Single pyelogram, other ureter occluded	17.5	11.5 mg 0.55 mg

CHOICE OF SOLUTIONS

In view of the effect of colloidal silver solutions on the renal parenchyma, as has been shown by various reports in recent medical literature, their use should be discontinued. Braasch and Mann,² in particular, have reported the results of comparative study of the effect of various mediums on the kidney. In addition to their toxic effects, they are expensive, viscid, possess undesirable physical properties, and are unstable in the presence of urine.

In being free from toxic and irritating effects and in giving fairly good technical results, the neutral thorium solution recommended by Burns is entirely satisfactory so far as I am aware. The fact that it had been used at one hospital in more than 500 cases as reported by Burns, and without any untoward results, is sufficient evidence as to its usefulness. One objection to its use is that the solution is prepared with some difficulty and is somewhat expensive if the prepared solution is purchased. To begin with, thorium nitrate is not a common salt

and often can be obtained only on a special order, and even then from only a limited number of large chemical houses. After the salt is obtained, a considerable amount of concentrated sodium citrate solution is required to redissolve the thorium which at first is precipitated. The citrate solution so prepared must be made neutral by the addition of the proper amount of alkali. However, this solution, as has been shown, possesses certain disadvantages. Of greatest importance is the fact that it is much more viscid than the iodid solution, requiring over 50 per cent more time for a given quantity to flow through the small tube of a viscometer. For this reason, under the same pressure much more of the iodid solution may be introduced into a kidney pelvis, for part of the capacity is always taken up by the urine excreted while the injection is taking place. Furthermore, the thorium solution has an osmotic pressure almost 50 per cent greater than the iodid, and it is evident that the ideal solution should have an osmotic pressure still less than that of the iodid, at least not greater than that of a concentrated urine. The thorium solution is slightly, but definitely, more toxic than the iodid when given intravenously in dogs. In conclusion, it should be remembered that the molar iodid solution has an opacity distinctly greater than that of the standard thorium preparation and, in practice, seems to me to give greater contrast on plates, owing equally to its lower viscosity and greater opacity.

The 25 per cent sodium bromid solution, which was recommended for pyelography by Weld some time after I had published two articles on the use of iodids for this purpose, naturally possesses many of the desirable features of the iodid solution. The chief advantages claimed for the bromid solution were that it was much less toxic than potassium iodid when given intravenously, and that it is much less expensive than any of the other mediums. It was also stated that in the same percentage concentrations the bromid and iodid solutions were of about equal opacity. These statements and their bearing on the selection of the most suitable medium for pyelography will be considered in greater detail. To begin with, the conclusion regarding the relative opacity of the bromid and iodid solutions is entirely erroneous. The fact that, when exposed to roentgen rays of the character of those used in pyelography, a molar (13.5 per cent) solution of sodium iodid has the same, or greater, opacity than that possessed by a 3 molar (25.2 per cent) solution of sodium bromid admits of no question. This has been established by my work as well as by previous investigations carried out by many physicists. And, in this connection, it is well to note again that there is no simple relation between the atomic weight of an element and its opacity to roentgen rays. It will also be noted that in his comparative toxicity tests, Weld used for the most part a 25 per cent solution of sodium bromid against a 25 per cent solution of potassium

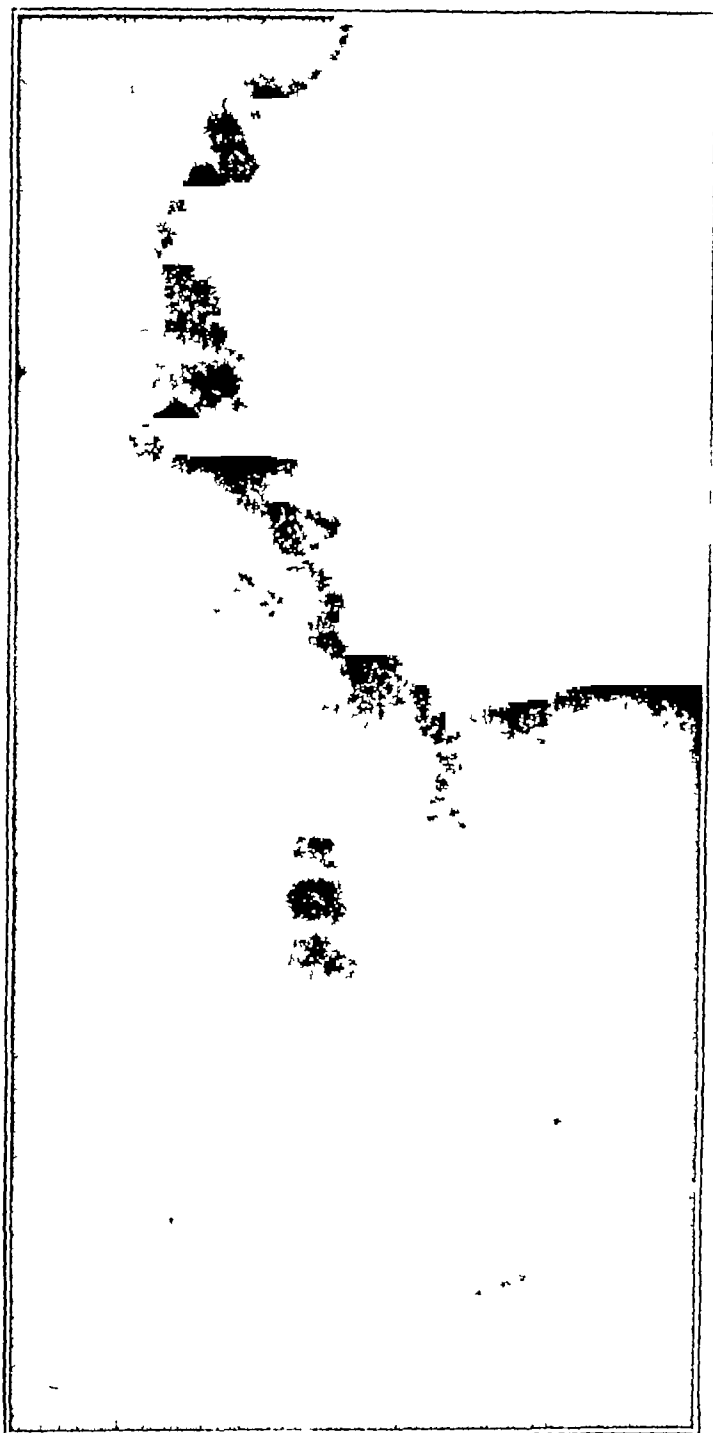


Fig 9 (Mr S) —Left ureterogram with 13.5 per cent sodium iodid solution. A shadow near the bladder seen in the original roentgenogram was localized by this ureterogram and can be seen in this plate as a dense center surrounded by a less dense zone lying at the lower end of the dilated ureter.

iodid Even so, very little difference was found in the effect of these two solutions on the kidney parenchyma itself But the great toxicity of potassium iodid when given intravenously in concentrated solution was especially emphasized The marked toxicity of potassium salts when introduced into the blood stream, in pure and concentrated solutions, has been known for many years If Weld had tested potassium bromid, he would have found it to be practically as toxic as the iodid, and, likewise, if he had tested sodium iodid, which I had even recommended as preferable to the potassium salt, he would have found it about as nontoxic as the sodium bromid, there being no appreciable difference in toxicity between a 25 per cent solution of sodium iodid and sodium bromid when given intravenously in dogs It is obvious, however, that for comparable results the molar (13.5 per cent) sodium iodid and the 3 molar (25.2 per cent) sodium bromid solutions must be used When given intravenously, these solutions are relatively non-toxic, and when introduced into the kidney pelvis cause no apparent changes or diminution of function as shown by the usual tests The question as to which of these two solutions is the better for pyelography probably will be established only after long experience It is true that, as far as expense is concerned, the bromid solution would be preferable A given volume of the bromid solution can be prepared at a cost much less than that of the same volume of iodid solution of the same opacity However, at present, 200 c c of the iodid solution costs about \$0.45, and, since on an average the amount of solution used for a pyelogram will not exceed 10 c c, the cost is seen to be quite moderate and should not be a great factor in the selection of mediums unless they are to be used in very large quantities

There are, however, several more or less valid reasons why, it appears to me, the iodid solution should be preferred

1 It is very probable that the iodid solution is less irritating to a kidney pelvis than the bromid At least, it may be stated definitely that the tongue is subjected to a more intense stimulation by the bromid solution

2 It is very probable, though not definitely proved, that the molar iodid solution is less toxic to tissues in general, including kidney parenchyma, than the 25 per cent bromid The reasons for this statement are first, a 25 per cent solution of sodium iodid given intravenously in dogs has apparently no greater toxic effect than a 25 per cent sodium bromid solution and the molar iodid solution, which is used in practice, is still less toxic, second, the 25 per cent bromid solution has an osmotic pressure over three times as great as that of the iodid This is a very important difference, as it is well known that, other conditions being equal, the toxicity of a solution to living tissues, in general, increases with the hypertonicity It happens that the cells of the

kidney tubules and of the pelvis are undisturbed by the presence of the hypertonic urine, but the molar iodid solution has a still somewhat greater hypertonicity than urine and, in that respect, fails to meet the requirements of an ideal medium, and by so much the more does the bromid solution fail to meet this requirement

3 The third quite real advantage possessed by the iodid solution is its marked relative increase in opacity to the roentgen ray as penetration increases. Physicists have commented on this property of iodine and have placed it in a group of elements exhibiting so-called selective absorption. This is of great practical importance in this way. Most of the technical difficulty in obtaining good pyelograms occurs in patients who have a great anteroposterior diameter at the level of the kidney, thus necessitating the use of greater roentgen-ray penetration. Under such conditions, the iodid solution casts a shadow which increases relatively in density as the penetration increases, while the bromid solution becomes relatively much less opaque. Therefore, to produce a shadow of the same relative density a much stronger solution of the bromid must be used.

SUMMARY OF RESULTS

1 The investigation of the comparative opacity of several pyelographic mediums shows that the molar, or 13.5 per cent, solution of sodium iodid is fully as opaque as the 3 molar or 25.2 per cent, solution of sodium bromid and is definitely more opaque than the standard neutral thorium solution, which is correctly designated as a 5/16 molar thorium nitrate solution, but is commonly called the "15 per cent" solution.

2 The kidney function as determined by the usual blood urea nitrogen and creatinin and by the phenolsulphonephthalein tests, both in the dog and in man, is not changed by the introduction of the molar and 4/3 molar solutions of sodium iodid into the kidney pelvis even when, experimentally, the latter was kept distended by the solutions at the secretory pressure of the kidney for twenty-five minutes. The same results were also obtained with the 3 molar sodium bromid solution.

3 When given intravenously in dogs, the 25 per cent sodium iodid, as well as the 25 per cent sodium bromid solution, produces no apparent immediate toxic effect. The blood pressure and respiration have remained unaffected when 50 c.c. of each of these solutions has been injected intravenously in a 30-pound dog within a period of ten minutes. The 13.5 per cent sodium iodid solution, however, is the solution used for pyelography. Solutions of potassium salts, whether bromid or iodid, are very toxic when given intravenously, a fact long known.

4 The comparatively rapid absorption of different substances from the kidney pelvis, as observed by Burns and Weld, is confirmed by the fact that the contents of the kidney pelvis of a dog one and a half to two hours after it has been filled with a molar or $4/3$ molar sodium iodid solution, which was retained in the pelvis by occluding the ureter, fails to respond to the usual chemical tests for iodid

5 The sensory stimulation or irritation of the kidney pelvis produced by the three different mediums investigated is probably very slight, but marked differences are obvious when tested on the tongue, the thorium solution causing the least stimulation and the 25 per cent bromid, the greatest

6 The viscosity of distilled water, the molar sodium iodid, the 3 molar sodium bromid and the standard thorium solutions, as determined by the ordinary viscometer, is represented by the figures 28, 29, 31.5 and 50, respectively. A low viscosity is a very important property for a good pyelographic medium, since the quantity of the medium which can be introduced into the kidney pelvis, other things being equal, varies inversely with the viscosity

7 The osmotic pressure of an average concentrated urine, of the molar sodium iodid, the 3 molar sodium bromid and the standard thorium solution is represented by the figures 2.7, 3.78, 13.47 and 5.52, respectively. From this it is evident that the iodid solution is the least hypertonic of the three mediums, and in this respect is far nearer the ideal than the bromid solution which has over three times as great an osmotic pressure, for it is well known that, other things being constant, the injury produced by hypertonic solutions on living tissues increases with the hypertonicity

8 For clinical use I have personally made twenty-two pyelograms, using sodium iodid varying in strength from 20 to 13.5 per cent. No serious reactions whatever have been seen. The number of patients who had more or less distress as a result of the pyelography is equaled by the number who suffered no additional discomfort whatever, and I am convinced that the additional discomfort was caused by over-distending the kidney pelvis

9 In the light of the foregoing experiments my previous conclusions are modified in two respects. First, in the article that I published in collaboration with Grandy, sufficient emphasis was not placed on the fact that the sodium iodid solution was preferable to the potassium, for it has been shown that the potassium salt is somewhat irritating and, in addition, because of its toxicity when given intravenously, it does not afford so great a factor of safety in the event of its absorption in large amounts. Second, increasing experience has demonstrated that instead of the 25 per cent solution of sodium iodid originally recommended, a molar or 13.5 per cent solution has been found to be sufficiently

opaque for all pyelographic work, and in this respect, at least, it equals and, when penetrating rays are used, always surpassed the 25 per cent bromid and the standard thorium solutions

10 The molar, or 13.5 per cent, sodium iodid solution now recommended is prepared by dissolving 15 gm. of the salt in a sufficient amount of water to make 100 c.c. In previous articles I have shown that such a solution is neutral in reaction, mildly saline to taste, non-irritating, and does not form precipitates with blood or urine

11 In conclusion, although the molar sodium iodid solution is not the least expensive of the pyelographic mediums, it nevertheless possesses certain distinct advantages which seem to me at least to make it the most suitable. Among these should be emphasized its freedom from toxic effects and irritation, as far as can be determined; its ease in preparation, the fact that it has the lowest viscosity and the lowest osmotic pressure of any mediums so far suggested, colloids and emulsions alone excepted, and the fact that it exhibits an opacity to roentgen rays which actually increases relatively with increasing penetration of the rays, definitely surpassing, in this respect, the thorium and bromid solutions

Hope-Methodist Hospital

THE DISTRIBUTION OF ADENOMYOMAS CONTAINING UTERINE MUCOSA *

THOMAS S CULLEN, M B

BALTIMORE

At a meeting of the Johns Hopkins Hospital Medical Society in March, 1895, I reported my first case of adenomyoma of the uterus, and since then I have been on the lookout for tumors of this character. From time to time the results of my labors have been recorded either in book form or in the literature.

I have been amazed at the widespread distribution of these tumors consisting of nonstriated muscle with islands of uterine mucosa scattered throughout them. In May, 1919, I read a short paper on the subject before the New York State Medical Society at Syracuse. This fragmentary article was published¹ a few months later.

In the present paper I shall not attempt to cover the literature on the subject, but I shall confine my remarks to a description of the cases and of the pathologic material that I have personally observed since reporting my previous cases.

Thus far I have found uterine mucosa in ten places in the body as indicated in Figure 1, and I shall therefore discuss the subject under the following heads:

- 1 Adenomyoma of the body of the uterus
- 2 Adenomyoma of the rectovaginal septum
- 3 Adenomyoma of the uterine horn, or of the fallopian tube
- 4 Adenomyoma of the round ligament
- 5 Uterine mucosa in the ovary
- 6 Adenomyoma of the utero-ovarian ligament
- 7 Adenomyoma of the uterosacral ligament
- 8 Adenomyoma of the sigmoid flexure
- 9 Adenomyoma of the rectus muscle
- 10 Adenomyoma of the umbilicus

* Address in surgery delivered before the Western Surgical Association in Kansas City, December, 1919.

* From the Gynecologic Department of the Johns Hopkins University and of the Johns Hopkins Hospital.

1 Cullen, T S. The Distribution of Adenomyomata Containing Uterine Mucosa, *Am J Obst* 80 130 (Aug) 1919.

ADENOMYOMA OF THE BODY OF THE UTERUS

These tumors may be limited to the anterior or posterior walls of the uterus, or they may form a mantle or zone just outside the uterine mucosa. When the uterus is cut open, it is noted that the anterior or posterior wall, or both, are thickened. This increase is due to a coarsely striated condition of the muscle directly beneath the uterine mucosa. Where the uterine walls are especially thick, the diffuse myomatous growth may be several centimeters in thickness. Scattered throughout the diffuse growth, one often notes small cystlike spaces filled with chocolate-colored contents, and not infrequently with a loupe one can detect here and there uterine mucosa penetrating into the diffuse growth.

Occasionally a cystlike space, 1 cm. or more in diameter, may be found in the thickened uterine wall. Such a space will usually be lined with a velvet membrane about 1 mm. thick, and the cavity will be filled with the characteristic chocolate-colored contents—old menstrual blood.

The line of demarcation between the normal outer uterine muscular wall and the diffuse myomatous growth just beneath the mucosa is invariably sharply defined, but the two are nevertheless so closely blended that it would be absolutely impossible to separate them. Occasionally such a uterus will contain one or more small discrete myomas.

The histologic picture in a typical case is very characteristic. The uterine mucosa is often of normal thickness and looks perfectly natural, but as we approach the underlying diffuse myomatous tissue the mucosa is seen to penetrate it in all directions, sometimes as an individual gland, but often large areas of mucosa are seen extending into the depth. In favorable sections, one can follow a prolongation of the mucosa half way through the uterus. Where the diffuse myomatous growth ends, the outward extension of the glands also ends.

In the course of time, portions of the diffuse adenomyoma may project into the uterine cavity and be expelled through the cervix as submucous adenomyomas. In other instances a portion of the growth is forced to the outer or peritoneal surface forming a subperitoneal adenomyoma. Such a myoma is prone to become cystic, and the cyst cavity or cavities will be filled with chocolate-colored contents.

Symptomatology—It is not difficult to figure out to what symptoms an adenomyoma of the uterus will usually give rise. In the first place, the mucosa lining the uterine cavity is perfectly normal, hence, as a rule, we shall have no intermenstrual discharge. With the advent of the menstrual period, however, the patient will not only lose her normal quota of blood, but this will be greatly increased by the flow coming from the large areas of mucosa which are scattered throughout the diffuse myomatous growth.

There will, as a rule, be a great deal of pain in the uterus at the period due primarily to the swelling of the mucosa which is scattered throughout the uterine walls. The small and medium-sized cystic spaces filled with chocolate-colored fluid are due to the accumulation of old menstrual blood in areas where the continuity of the mucosa with the uterine cavity has been interrupted. Such areas also undoubtedly add to the feeling of distention and discomfort at the period.

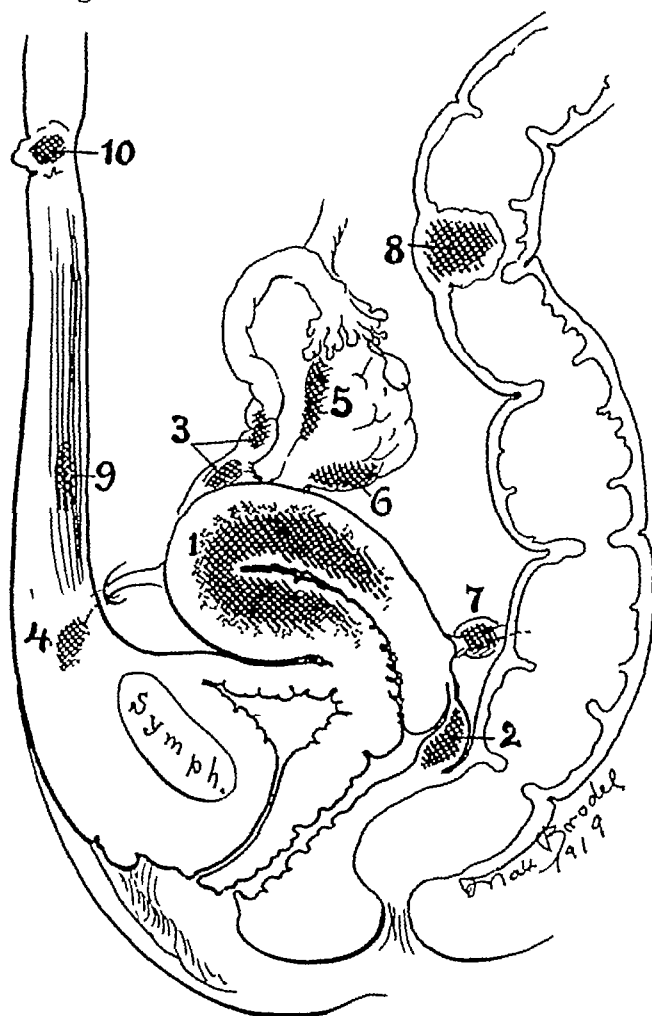


Fig 1—The various points at which I have found uterine mucosa 1 in adenomyoma of the body of the uterus, 2 in adenomyoma of the rectovaginal septum, 3 in adenomyoma of the uterine horn or fallopian tube, 4 in adenomyoma of the round ligament, 5, in the hylum of the ovary usually unaccompanied by a myomatous growth, 6, in the utero-ovarian ligament, 7, in the uterosacral ligament, 8 in the sigmoid flexure, 9, in the rectus muscle, 10 in adenomyoma of the umbilicus.

On bimanual examination, the uterus is found to be normal in size and perfectly smooth, or, on the other hand, it may be two or three times its normal size and slightly nodular. The introduction of a uterine sound usually reveals a normal cavity, and on curettage normal mucosa is invariably found. From the clinical findings one can often make a fairly accurate diagnosis of adenomyoma.

Generally speaking, removal of such a uterus is clearly indicated. Frequently this proves rather difficult on account of the tendency for such an organ to become densely adherent to surrounding structures.

I have discussed adenomyomas of the body of the uterus in such detail elsewhere² that a further consideration of the subject here would be superfluous.

CASE 1—A bicornate uterus with diffuse adenomyoma of the right horn. Pregnancy in the right fallopian tube. Adenomyoma and hydrosalpinx of the left tube. Large cyst of the left ovary (Figs 2, 3, 4, 5 and 6)

History (Church Home and Infirmary, No 19173)—Mrs H T, aged 36, admitted to the Church Home and Infirmary, May 21, 1918, and referred to me by Dr Marshall G Smith, complained of an abdominal tumor, increasing pain in the right lower abdomen and vaginal bleeding.

The menstrual periods as a rule had been regular, lasting two days, and she had had pain in the right lower abdomen. Latterly the periods had been irregular. The last normal period began probably Feb 25, 1918. During March and April, she had had no menstrual period, but had suffered from the usual right-sided pain. She again had noted a flow on May 1, which had lasted one day. Two days had elapsed and then she had had a flow for seven days. The patient had been married twice, but had had no children and no miscarriages.

On examination under anesthesia, I made out what appeared to be a myomatous uterus which extended well up toward the umbilicus.

Operation and Result—Operation was performed May 28. When the abdomen was opened we found the tube on the right side 4 cm in diameter, and adherent in the pelvis. The uterus was bicornate, and the right side was three times the natural size. The surface of one of the nodules had a brownish appearance suggestive of an adenomyoma. On the left side was an ovarian cyst which filled the pelvis and was glued down by adhesions. We removed the structures from left to right and then took out the appendix which was tied down. The abdomen was closed without drainage. The patient made a good recovery and was discharged, June 18.

Examination of Specimen (Gyn Path No 25515)—The specimen consists of the pelvic structures intact (Figs 2 and 3). The uterus has been amputated through the cervix. This portion consists of a right and left uterine horn. The right horn is 9 cm. long and 5.5 cm broad. This has two or three small bosses projecting from its surface, the largest being 1.5 cm. in diameter. The surface of the last and some of the others and also the adjoining peritoneum has a rusty appearance instantly suggesting adenomyoma. On the anterior surface of the uterus are a few adhesions, on the posterior surface, many fanlike adhesions.

Intimately blended with the right enlarged uterine horn is a left uterine horn. The two horns are separated from each other by a cleft, about 1.5 cm deep anteriorly, but very shallow posteriorly. The left horn to the point of amputation of the cervix is 7 cm long and about 3 cm broad.

² Cullen, T S. Adenomyoma uteri diffusum benignum, Johns Hopkins Hospital Reports 6 133, 1896, Adenomyome des Uterus, Berlin, August Hirschwald, 1903, Adenomyoma of the Uterus, J A. M. A 50 107 (Jan 11) 1908, Adenomyoma of the Uterus, Philadelphia, W B Saunders Company, 1908.

On section, it is seen that both the right and the left horns have separate cavities. These apparently unite near the external os.

The right horn on section presents the typical picture of adenomyoma (Fig 4). The anterior wall of the right horn reaches a thickness of more than 4.5 cm. There is no vestige of normal muscle persisting. The entire wall of the uterus both anteriorly and posteriorly shows the striated picture characteristic of adenomyoma, and scattered everywhere throughout both the anterior and posterior walls are chocolate-colored areas varying from 1 mm to 5 mm in diameter, while small chocolate-colored cysts are also found in the myomatous nodules on the surface of the uterus.

The walls of the left uterine horn present the normal appearance.

The right tube near the uterus is about 8 mm in diameter. As it passes outward and downward, it reaches a diameter of 4 cm. On section, it is found to be filled with what looks like organized blood (Fig 3).

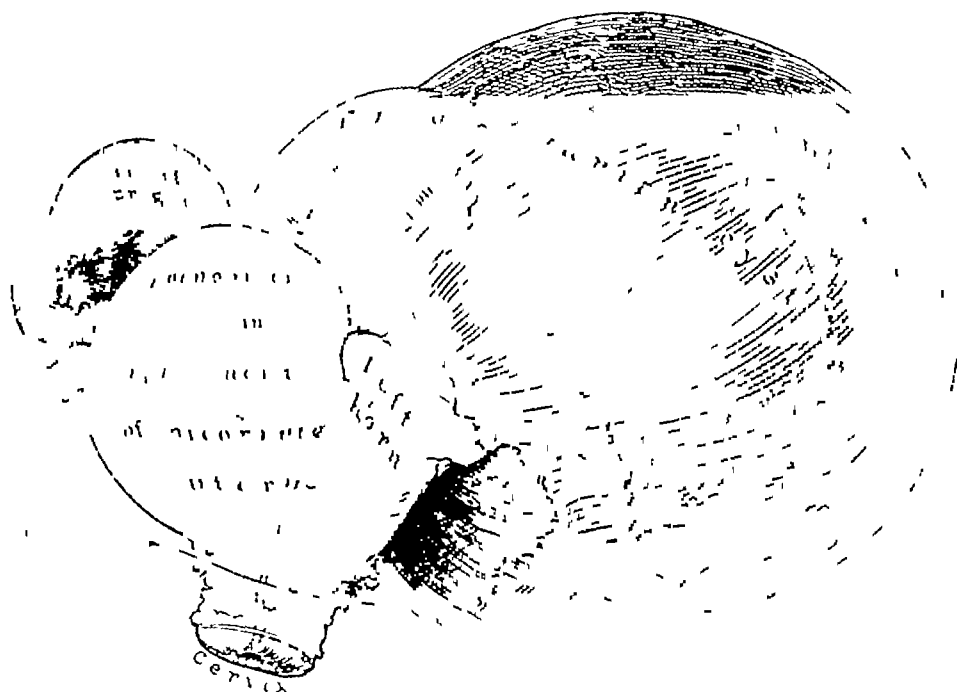


Fig 2 (Case 1)—A bicornuate uterus with adenomyoma of the right horn, right tubal pregnancy, enlarged left tube, the inner end showing adenomyoma (Fig 6), the outer end hydrosalpinx, left ovarian cyst. For the finer details see Figure 3.

The left ovary has been transformed into a thin-walled multilocular cyst, 16 cm in diameter. Its walls in places are as thin as parchment. The left tube at the uterine cornu is fully 1 cm in diameter. As it passes outward it comes to measure about 2.5 cm in diameter, and the walls are very thin.

Histologic Examination—Right Uterine Horn. Sections have been made embracing the entire thickness of the uterus (Fig 5). The musculature is divided up into diffuse whorls, varying from 5 mm to 3 cm in diameter. Some of these are oval or circular, others are long and run parallel to the cavity of the uterus. Scattered everywhere throughout the walls of the uterus are dark areas containing minute cavities in their centers. Some of these cavities have a definite lining fully 1 mm in thickness. In various places are oval or irregular cystlike spaces varying from 1 to 4 mm in diameter. The



Fig. 3 (Case 1) —Bicornate uterus, right tubal pregnancy, enlarged left tube, left ovarian cyst. Viewed from the front. The uterus has been amputated through the cervix. The right cornu is much enlarged and projecting from its surface are two small fibroids. Beneath the anterior fibroid, the surface of the uterus is somewhat puckered. At this point the adenomyoma had extended to the peritoneal surface. A longitudinal section of the right horn is shown in Figures 4 and 5. The left uterine horn is relatively small. The left tube in its inner portion is almost solid and consists of typical adenomyomatous tissue (Fig. 6). The outer end of the tube has been converted into a hydrosalpinx. The ovarian cyst seemed to be of the retention cyst variety.

majority of these are partially filled with blood. Even with the naked eye the diagnosis of diffuse adenomyoma occupying both the anterior posterior uterine walls is perfectly evident.

With a higher power, islands of normal-appearing uterine mucosa are seen scattered everywhere throughout the diffusely thickened uterine walls, and the glands extend right up to the peritoneal surface. Even the isolated glands are accompanied by the characteristic stroma. In this case, the muscular tissue immediately around the islands of mucosa is unusually dense. Some of

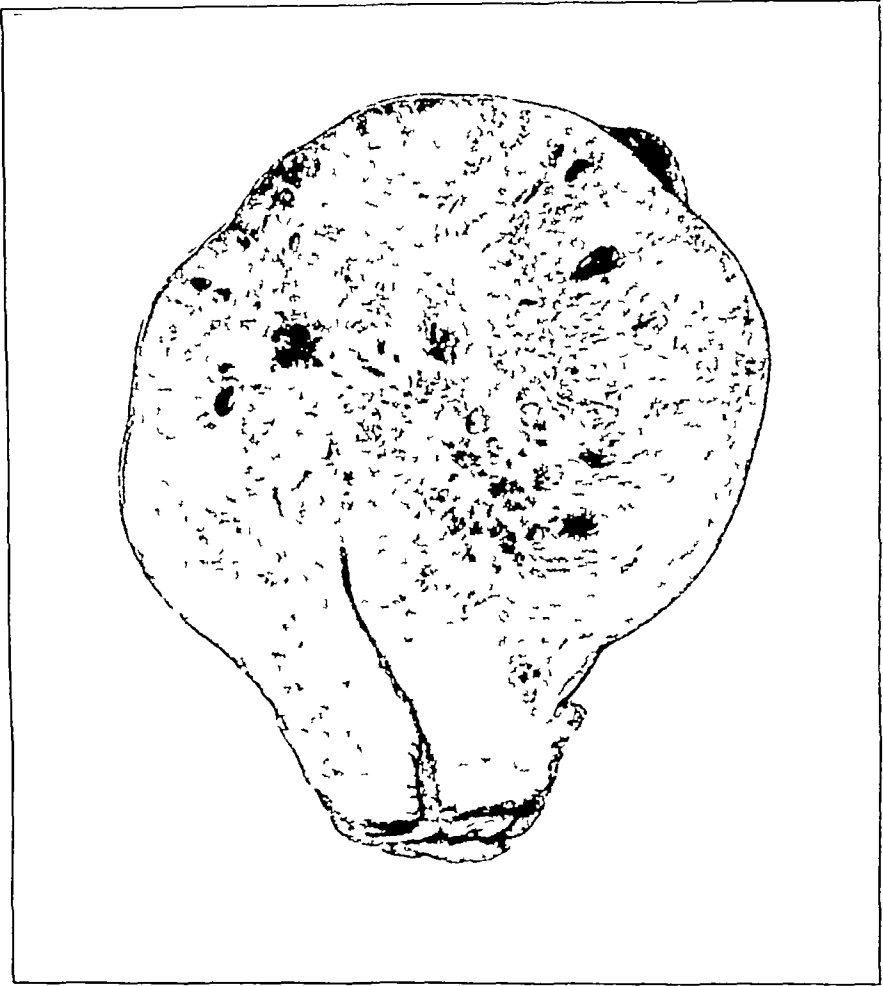


Fig. 4 (Case 1)—Adenomyoma of the right uterine horn. This is a longitudinal section through the right horn of the uterus shown in Figure 3. The entire body of the uterus shows a diffuse myomatous thickening, and scattered throughout the walls are small cystlike spaces. These were in the main filled with chocolate-colored contents. The diffuse adenomyoma extends right up to the peritoneal surface at most points. At the fundus a discrete myomatous nodule can be seen. For the low power picture of the adenomyoma see Figure 5.

the blood at the menstrual period has undoubtedly escaped to the peritoneal surface, thus accounting for the rusty appearance noted on the surface of the uterus at operation.

This is the most widespread adenomyoma of the uterus that I have ever seen. The mucosa lining the cavity of the uterus is perfectly normal. In a few places however, it shows some tendency to extend into the underlying muscle.

Right Side Sections from the blood clot in the right tube show quantities of placental villi. On some of these both Langerhans' layer and syncytium are still visible, and one is also able to make out syncytial buds. At other points, the villi have lost all trace of epithelium. No cellular structure is visible in the stroma, and the cells are recognized as mere shadows. Their contours are still perfectly preserved. We are dealing with a right-sided tubal pregnancy, and as we look back over the history we find that the menstrual cycle strongly indicated extra-uterine pregnancy, but that the relatively large size of the pelvic masses completely overshadowed the enlargement of the tube.

Left Side As was noted macroscopically, the left tube even near the uterus is unusually large. A section taken 2 cm beyond the uterine horn is 1 cm in diameter. Even with the low power it is noted that it is almost solid (Fig 6). Its center is occupied by diffuse myomatous tissue, and scattered everywhere throughout this are glands which resemble in every particular uterine glands. The majority of these lie in direct contact with the muscle, but here and there are several glands embedded in the characteristic stroma of the uterine mucosa. Some of the glands are dilated and at one or two points we can see miniature uterine cavities. We have in this tube an adenomyoma of the uterine type, and I am totally at a loss to explain its mode of origin.

Sections from the large ovarian cyst show that the largest cavity is lined with epithelium that is almost flat. In the walls of this large cyst are a few glandlike spaces lined with cuboidal epithelium. The cyst walls are composed of laminated fibrous tissue.

In this case, we have a most unusual combination—a bicornate uterus, the right horn of which presents a most beautiful example of diffuse adenomyoma, a right tubal pregnancy, adenomyoma of the inner end of the left tube and a hydrosalpinx of its outer end, and finally, a large multilocular cyst of the left ovary apparently of the retention cyst variety.

ADENOMYOMA OF THE RECTOVAGINAL SEPTUM³

I wish to lay unusual emphasis on this group of cases. Many of you have undoubtedly seen them, but may not have recognized them. They are of unusual importance, and, if overlooked, will in time cause the patient to become a chronic invalid, and in some instances will undoubtedly lead to her death.

In 1913, Dr D S D Jessup of New York, knowing my interest in adenomyomas, sent me specimens of two tumors of this class. The mail on the following morning brought me the *Proceedings of the Royal Medical and Chirurgical Society of London*, containing Cuthbert Lockyer's splendid article on "Adenomyoma of the Rectovaginal Septum." These two communications set me thinking, and I at once felt sure that two of my cases undoubtedly belonged in this category,

³ Cullen, T S. Adenomyoma of the Rectovaginal Septum, *J A M A* **62** 835 (March 14) 1914, *Tr South Surg & Gynec A* **26** 106, 1913, *A Further Case of Adenomyoma of the Rectovaginal Septum*, *Surg, Gynec & Obst* **20** 260 (March) 1915, *Adenomyoma of the Rectovaginal Septum*, *Bull Johns Hopkins Hosp* **28** 343 (Nov) 1917.



Fig 5 (Case 1) —Diffuse adenomyoma of the uterus. This is a long slit *a*, noted in the lower and right portion of the picture, represents the uterine whole present the usual appearance. The posterior wall of the uterus is a diffuse myomatous thickening, and where the muscle is arranged in whorls are dilated, forming round, oval, or irregular cyst cavities. The glands extend adenomyoma of the uterus.



n through the right horn of the uterus shown in Figures 3 and 4. The longitudinal
 It can be traced upward and toward the left. The glands of the mucosa on the
 thickened and the anterior wall markedly so. The greater part of the uterus presents
 nearly always a gland or a colony of glands in its center. Many of the glands
 p to the peritoneal surface. The picture is that of a most pronounced diffuse
 arms of the uterus. The is a
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 The posterior wall of the uterus
 d where the muscle is arranged
 irregular cyst cavities. The

although the histologic examination had given no inkling of such a condition I had many more sections made and was finally rewarded by finding in each case the typical picture in other portions of the specimen. Since then I have been on the lookout for this condition and have had nineteen cases.

Adenomyoma of the rectovaginal septum usually starts just behind the cervix, and on bimanual examination, one can feel in this region a small, somewhat movable nodule scarcely more than a centimeter in diameter. The rectal mucosa at this time can be made to slide perfectly over the tumor.

As the growth increases in size, it spreads out laterally and at the same time becomes blended with the adjacent anterior rectal wall. Later it may invade the broad ligaments, encircling the ureters, or may envelop pelvic nerves. With the extension of the growth, it may push down into the posterior vaginal vault forming definite and well-formed vaginal polypi, and finally, it may break into the vagina.

The histologic picture is typical of adenomyoma, even the vaginal polypi consist of nonstriped muscle and uterine mucosa covered over by vaginal mucosa. Where the growth has definitely broken through into the vagina, we have normal-appearing uterine mucosa lining portions of the vaginal vault.

The clinical picture in adenomyoma of the rectovaginal septum is typical. In the early stages, the patient comes complaining of much pain just before and at the beginning of the period especially at the time of defecation. On bimanual examination a small nodule is felt directly behind the cervix.

When the process is more advanced, the growth may measure 2 or 3 cm across and may bulge slightly into the rectum, while in some cases there is already marked thickening of the anterior rectal wall for a distance of several centimeters, and at the period there may be some rectal bleeding.

The growth sometimes encircles one or both ureters. At the period, the tumor tissue naturally swells up, and it may so constrict one or both ureters that there is a damming back on one or both kidneys with consequent pain in the renal region. In other cases when the pelvic nerves are caught in the growth, excruciating pelvic pain may be experienced as soon as the tumor becomes congested at the time of menstruation.

Occasionally as the growth progresses, the polypoid condition in the vaginal vault directly behind the cervix becomes very prominent, and in those cases in which the growth breaks through the vaginal mucosa, there may be a menstrual flow from the vaginal vault even when a supravaginal hysterectomy has been performed some years before for uterine myomas. Finally if nothing is done the pelvis

may become so choked with the growth that the patient dies from the extreme loss of blood coupled with partial intestinal obstruction

In the early stages of the growth, this condition should be readily diagnosed. It cannot at this time be confused with any other pelvic lesion.

Treatment—In the very early stages it may be possible to open up the vaginal vault just behind the cervix and remove the tumor. As

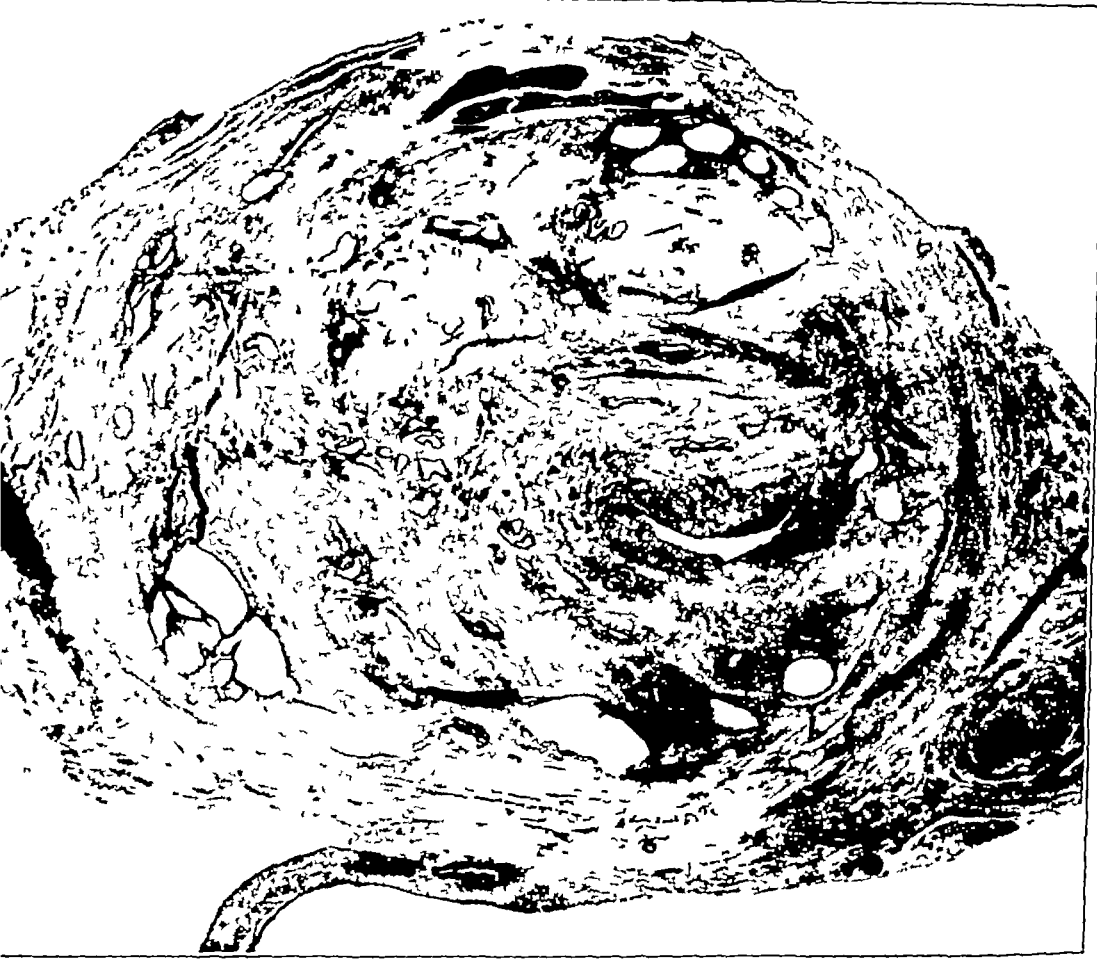


Fig. 6 (Case 1)—Adenyomyoma of the left fallopian tube. This section was taken from the left tube seen in Figure 2, about 2 cm. distant from the uterine horn. Here the lumen of the tube is almost completely replaced by a diffuse myomatous growth with isolated glands or groups of glands scattered throughout it. The majority of the glands lie in direct contact with the muscle, a few are surrounded by the characteristic stroma of the uterine mucosa. Quite a number of the glands in the outlying portions have become dilated, forming small cysts. Hitherto I have never seen the lumen of the tube occupied by an adenyoma. The distal end of the tube formed a hydrosalpinx.

as a rule, however, it involves the posterior part of the cervix and cannot be shelled out.

When the nodule is 1 cm. or more in diameter and is still freely movable, the abdomen should be opened, the ureters isolated and the uterus with a cuff of vaginal mucosa removed. If the vagina is cut



Fig 7 (Case 2)—Adenomyoma of the rectovaginal wall as seen on vaginal inspection. This water color of the uterus and accompanying vaginal cuff was made by Mr Brödel shortly after operation. The cervix itself is practically normal. Projecting from its surface are a few small Nabothian follicles. Just posterior to the cervix is a slightly bluish black cystic area about 6 mm in diameter. This bluish black appearance is, of course, due to the accumulation of old menstrual blood in a small cystic area in the adenomyoma. The uterus itself is little if any enlarged. For the appearance of the adenomyoma on section see Figure 8 and for the microscopic picture see Figure 9.

completely across, one can then lift the uterus and vaginal cuff up and with more ease separate the adherent vaginal cuff from the rectum. Sometimes it will be necessary to remove a wedge of the adherent anterior rectal wall with the uterus.

In cases in which the growth is widespread, a preliminary permanent colostomy is imperative. Later the pelvic structures can be removed *en bloc*. The removal of an extensive adenomyoma of the rectovaginal septum is infinitely more difficult than a hysterectomy for carcinoma of the cervix.

When a hysterectomy has been performed, and a small portion of the growth has been left on the rectum, radium seems to have held the rectal growth in check.

Since my last paper on adenomyoma of the rectovaginal septum appeared I have had ten more cases. The majority of these were early cases, and it is in the early cases that we naturally get the best results. History will undoubtedly repeat itself. Twenty-five years ago, a subacute or chronic appendix was rarely removed, but appendix abscesses were drained. Now the appendix is, in the vast majority of cases, removed in time. In less than ten years, I feel sure that the surgeon will recognize and operate on these adenomyomas of the rectovaginal septum long before the wall of the rectum or the broad ligaments have been involved. Given a small nodule directly behind the cervix with little evidence of pelvic infection, the diagnosis is relatively certain. If the abdomen is then opened and the rectum is found lifted up and adherent to the posterior part of the cervix, the chances are nine out of ten that an adenomyoma of the rectovaginal septum exists. When early operation is performed in these cases, a certain number of our "mild pelvic inflammatory cases" that heretofore have gone from bad to worse will be cured. In the first week of November of this year, I saw three early cases of adenomyoma of the rectovaginal septum—all of the patients being residents of Baltimore.

Recently I received a letter from a surgeon in South America in which he sketched his case from the early to the inoperable stages. The history is so graphically given that I believe we shall all profit by hearing it.

Valparaiso, Oct. 18, 1918

Dear Sir:

Having found your articles on 'Adenomyoma of the Recto-Vaginal Septum' of special interest I take the liberty of sending you details of a case which was a puzzle to two other surgeons and myself until I luckily saw a synopsis of your article on this disease in *Surgery Gynecology and Obstetrics*. The said article cleared up a mystery which I had been trying to solve for months as it is impossible to find details of such cases in well-known text-

books in English, German or French I think it will be of interest for you to know of such a case and hope you will have patience to read this letter which I make as short as possible

Mrs H, aged 30, nullipara, of good health, married two years ago, consulted us (in British and American Hospital) at the beginning of December, 1917, complaining of lumbago. On making a vaginal examination, we asked her about the menses which she said had been of late painful on the right side, the uterus was normal in position, size, consistency, etc. On the right side, the ovary was painful, but the puzzle was that she had a nodule especially hard and painful near the uterus which we took to be localized parametritis. We advised her to take douches, baths, ichthyol suppositories, etc, but seeing we got no result and that the pain was excruciating during the next period we decided to make a laparotomy.

On January 3, we performed a median laparotomy finding a right ovary large and of a very dark, unhealthy color. The nodule mentioned before was in the broad ligament right over the vagina, and it being impossible to remove it by abdomen, we resolved to leave it. The uterus was normal so we left it as it was, removing the ovary.

For three months, the patient experienced relief in symptoms, but on the fourth month menstruation was very painful and the pain radiated down to the thigh. We made again a vaginal examination and greatly to our disappointment found now two hard nodules, the same one as before much increased in size and a second one in the recto-vaginal septum which was easier to touch by rectal examination. The pain on palpation was terrible, so we had to give the patient a few drops of ether to examine carefully.

Seeing the condition of affairs, we had a consultation with a third surgeon and he was as much puzzled as we were. We decided to remove these little tumors by the vaginal route.

On May 28, we removed the two tumors by the vaginal route and our pathologist reported adenocarcinoma of an unusual type.

Looking for some information on this subject, I came across the article already mentioned and immediately sent for the more lengthy article in the *Johns Hopkins Bulletin* which I received the day before yesterday and which has cleared up the condition of affairs to us and corrected the pathologist's diagnosis.

Unluckily our patient's condition is now too bad for us to think of doing a complete hysterectomy and we think she will not live very long. She has not had as yet any rectal hemorrhage, but she has had ovarian insufficiency, very irregular menstruation and her general state is very poor. Locally the condition of the pelvis is one firm mass as you say, like glue.

As I have not been able to procure your former articles, I beg your patience to answer one or two questions by post.

Where does this abnormal muscular and glandular tissue come from? From the uterus, or are these sometimes remains of fetal tissue or rather embryonic tissue which suddenly give rise to the growth?

Thanking you for the special service rendered to us through your articles and hoping you will let me know of any further researches in this line, believe me,

Yours truly,

JOHN WILSON, M D

REPORT OF CASES OF ADENOMYOMA OF THE RECTOVAGINAL SEPTUM
HITHERTO UNPUBLISHED

CASE 2 (Septum Case 10) — *Adenomyoma of the rectovaginal septum recognized as an indurated area just posterior to the cervix, and by a small bluish black cyst shining through the vaginal mucosa* (Figs 7, 8 and 9)

History (C H I No 18650) — Mrs M L, aged 41, was admitted to the Church Home and Infirmary, March 6, 1918, complaining of pain in the right

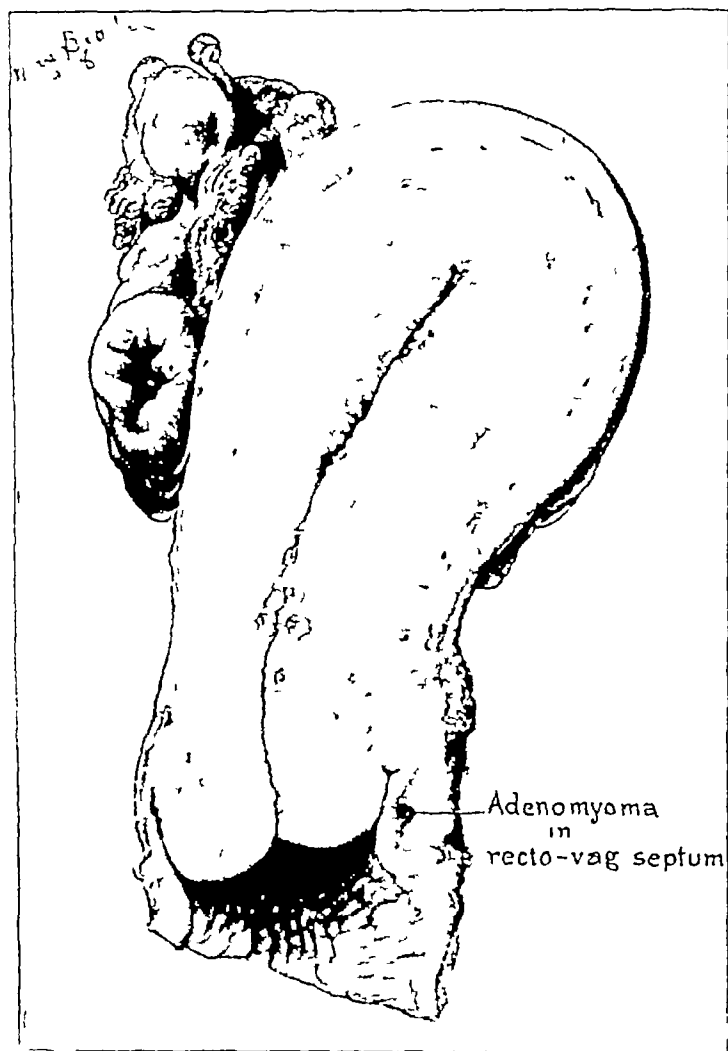


Fig 8 (Case 2) — Adenomyoma of the rectovaginal septum. This is a longitudinal section of the uterus and vaginal cuff seen in Figure 7. Near the internal os are a few small cysts otherwise the uterus presents the normal appearance. The anterior vaginal wall is normal. In the posterior vaginal wall near the cervix is an area of thickening with small dark areas scattered throughout it. On histologic examination (Fig 9) it presents the typical picture of an adenomyoma.

lower abdomen associated with menstruation. Her general health had not been good. She had had pleurisy in 1916.

Her menses began at 13 were regular, painful and lasted seven days. Since November, 1917, the periods had been about three weeks apart and exceedingly painful. The last period was shortly before her admission.

Her present illness dated back one and a half years when she had an acute attack of pain in the right lower abdomen reaching to the back. This was definitely associated with menstruation. She had always gone to bed on the first day of the period and at times would become giddy and faint. For a year and a half, there had been a great deal of pain in the right lower abdomen at the time of the period. This pain would be sharp and radiating.

Examination—When the patient was admitted to the hospital, she was in a very nervous and run down condition and her period was just over. Dr Edmond H Teeter, the resident who made a pelvic examination, told me

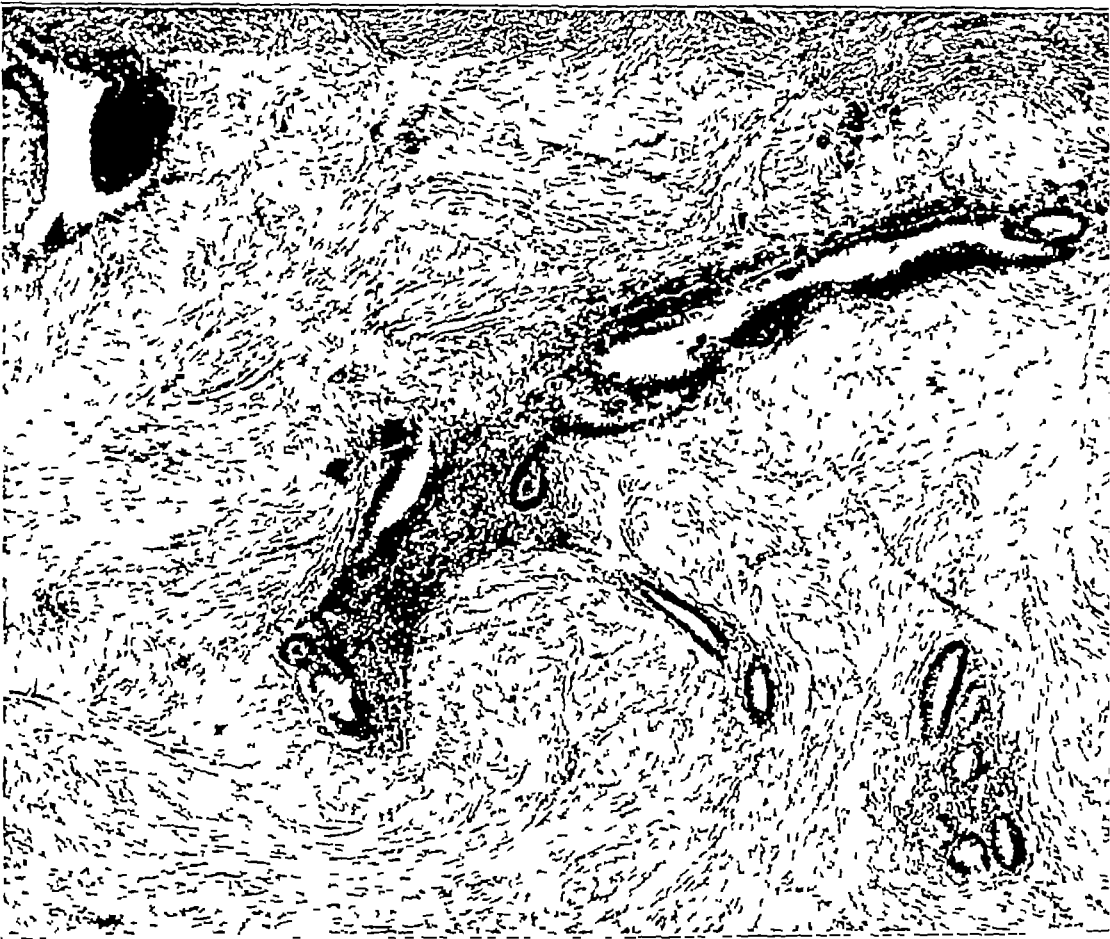


Fig 9 (Case 2)—Adenomyoma of the rectovaginal septum. The majority of the glands are accompanied by the characteristic stroma of the mucosa. A few lie in direct contact with the muscle. For the appearance before operation, see Figure 7. A longitudinal section of the uterus and rectovaginal septum is shown in Figure 8.

before I had seen the patient that she had an adenomyoma of the rectovaginal septum. This was perfectly definite, as just posterior to the cervix was an area of induration about 2 or 3 cm across and probably 1.5 to 2 cm thick. On rectal examination, the anterior rectal wall seemed splinted.

Operation and Result—March 26, 1918, we made a median incision and found a corpus luteum cyst, 5 cm in diameter, on the left side. The left tube and ovary were at once removed. The uterus was gradually dissected free as far as its vaginal attachment, and both ureters were carefully dissected out.

The vagina was cut across all the way around, after which adhesions to the rectum were got at from the under side. It was possible to remove the growth without going into the lumen of the bowel at all. There was considerable oozing which was readily checked. Two drains were left in the pelvis and brought out through the vagina, one in the lower angle of the incision. The patient made a perfectly satisfactory recovery and was discharged April 21, 1918.

At the time of operation a small bluish black cyst was noted in the vagina directly behind the cervix (Fig 7). This bluish black appearance clearly indicated that we were dealing with an adenomyoma.

A longitudinal section of the uterus (Fig 8) shows that the organ is only slightly altered. In the vaginal wall just behind the cervix, however, is an area of thickening and this shows the characteristic areas of hemorrhage invariably associated with an adenomyoma.

Histologic Examination (Gyn Path No 25514)—A section through the posterior vaginal wall at the point where the bluish black cyst was noted shows that the vaginal mucosa is normal. The underlying tissue consists of nonstriated muscle running in all directions. The cyst noted clinically is lined with low cuboidal epithelium. It is partially filled with old blood which presents a granular appearance, and in the blood are exfoliated epithelial cells which are swollen, have become spherical and are filled with yellowish brown pigment. Some of the epithelial cells lining the cyst present precisely the same picture. Projecting into the cyst cavity at one point is a tongue-like mass of normal uterine mucosa. The surface of this is covered with high cylindric epithelium. Beneath it is the characteristic stroma of the mucosa, and embedded in this stroma is a uterine gland which is continuous far into the depth of the myomatous tissue. Scattered at various points throughout the diffuse myoma are islands of typical uterine mucosa (Fig 9), some presenting the usual appearance, others showing old hemorrhage. The stroma cells of the mucosa in such areas are swollen and have taken up yellowish brown pigment.

The mucosa lining the cervix and cavity of the uterus is normal.

In this case, the adenomyoma is lower down than usual and appears to have begun in the posterior vaginal wall rather than in the posterior part of the cervix.

CASE 3 (Septum Case 11)—*Adenomyoma of the rectovaginal septum* (Figs 10 and 11)

History (Gyn No 24601)—Mrs C S F L, aged 41, came to see me on Jan 6, 1919. She looked perfectly well but complained of pain in the lower part of the abdomen when she walked, and of excruciating pain in the midline above the symphysis at the time of the periods. She was also suffering a great deal of discomfort when the bowels moved.

The patient began to menstruate at 12, and was perfectly regular. The flow for the last three years had been very free, the periods persisting for six days. There was a great deal of abdominal pain on the third day. The last period was three weeks before her admission. She said she had a yellowish discharge between periods which at times was most irritating. The patient had had four children, no instruments were used in the deliveries.

Examination—I found the abdomen to be perfectly uniform. There was a small hernia at the umbilicus 3 mm in diameter. The outlet was moderately relaxed, the cervix was forward and slightly lacerated and a little nodular thickening about 1.5 cm in diameter could be felt distinctly directly behind

the cervix The body of the uterus was not enlarged, but was sagging backward Rectal examination revealed the thickening posterior to the cervix very clearly

Operation and Result — The patient was admitted to the Johns Hopkins Hospital, Jan. 19, 1919, and operated on the following day After tying off the round ligaments and opening up the broad ligaments, we tied the uterine vessels and isolated both ureters We found a little puckering and thickening just posterior and a little to the right of the cervix near the right uterosacral ligament We cut both uterosacral ligaments, turned down the bladder peritoneum, controlled the vaginal veins and then cut the vagina across all the way around This enabled us to lift the uterus and rectum well up so that the nodule posterior to the cervix could be attacked from the under side The growth was gradually loosened and separated from the rectum completely We were able to accomplish this with the minimal amount of bleeding The growth in the rectovaginal septum was about 15 cm in diameter, and where the cervix had become adherent to the rectum, the puckered area had developed As we lifted the cervix away from the rectum, there was an escape of a little old blood The patient stood the operation perfectly We removed the appendix and put two drains into the pelvis, bringing them out through the vagina The patient made an excellent recovery and was discharged, Feb 13, 1919

On Saturday morning, June 29, 1919, five months after operation, the patient was taken with intense discomfort, not exactly pain, in the epigastrium This was not very severe and in spite of it she went to Annapolis On her return, there was no improvement, but she had a fair night with the aid of an opiate On Sunday morning, Dr Frank R Smith was called but could discover no alarming symptoms There was no abdominal pain, and no pain on palpation of the abdomen Magnesium citrate and bismuth were prescribed and the bowels moved well There was no blood passed in the stools The patient vomited, but there was no unusual odor to the vomitus Sunday evening, a hypodermic was given, and the patient rested until 2 o'clock Monday morning On awakening, she complained of a more generalized pain and of a distress that was rhythmic in character A little liquid nourishment was given, but this was immediately vomited About half past six, an enema was given, and the water returned clear and free from blood Suddenly the patient fell over, gasped a few times and died The husband, who was a physician, noted the rapid heart beat and abnormal coldness of the arms some time before death There was no clamminess or dyspnea noted at this time

Necropsy Findings (J H H Necropsy No 5933) — This was performed by Dr R G Mills When the abdomen was opened the omentum was found firmly adherent to the under surface of the scar At no point were there adhesions between the omentum and loops of intestine As the intestines came into view, they appeared somewhat distended, a little dark in color The lowermost loop was very dark and purplish, and the serosa of this dark colored loop had to some extent lost its luster, and the subcutaneous tissue appeared infiltrated with blood There was a small amount of free, clear straw-colored fluid in the peritoneal cavity, and there were a number of small adhesions that connected the various loops of intestine It was rather difficult to unravel the abdominal picture

Dr Mills' summing up is as follows "Beginning at the point where the jejunum joins the ileum the bowel passes beneath the mass of adherent intestine, it passes under a fold of mesentery, it emerges below in the region of the cecum and is there united with another loop of bowel by a long, slender

strong band of adhesions. The ileum now passes into a long loop that circles around and is adherent once more to the long adhesion just mentioned. Just above this attachment the ileum is kinked into an S-shaped mass as the result of adhesions which attach contiguous mesenteric surfaces. The bowel then passes on in another loop returning beneath this long slender adhesion. At this point the lumen of the ileum is abruptly decreased in caliber and beyond this point is much smaller. At the point of constriction, the serosa is very deeply injected and somewhat consolidated. The bowel is much firmer by reason of a hemorrhage at the point where obstruction occurs.

"Subsequent to operation, it is probable that adhesions formed between contiguous loops of bowel. These have organized, producing distortion of the lumen of the bowel. The adhesions are probably responsible for the long slender adhesion above mentioned. Probably at the onset of the present acute attack a twist of the whole mass has occurred producing in effect a volvulus. This has thrown unusual tension on the narrow band which, producing a bridge-like form, has allowed a loop of ileum to pass beneath it."



Fig 10 (Case 3)—Adenomyoma of the rectovaginal septum. Springing from the posterior surface of the uterus are a few small myomas. Growing from the posterior surface of the cervix just below the peritoneal attachment is a rough nodular growth. This on histologic examination showed typical adenomyoma (Fig 11). As a rule, I never remove normal ovaries, but in some cases of adenomyoma of the rectovaginal septum it is necessary to leave a small portion of the growth attached to the rectum, and if the ovaries are saved there appears to be a tendency for the remaining portion of the adenomyoma to continue to grow.

Dr Mills' findings disclose clearly the fact that intestinal adhesions had followed the abdominal operation and that several months later there was a sudden volvulus of the adherent intestinal mass producing acute obstruction. It is remarkable to find a patient succumbing so quickly after the symptoms of partial obstruction developed. It will be noted, however, that the upper part of the small bowel was much involved. In such cases alarming symptoms usually develop relatively early.

Examination of Specimen (Gyn Path No 24657).—The specimen consists of the uterus with the appendages intact (Fig 10). The uterus is 9 cm long, 5 cm broad and 5 cm in its anteroposterior diameters. Both the anterior and posterior surfaces are smooth. In the posterior wall of the uterus are two small fibroids. These project a little from the surface. Springing from the

posterior wall of the cervix is a small, irregular growth about 15 by 1 cm. This is intimately blended with the cervical wall. In the depth, it contains several small bluish black areas.

There is a slight rolling out of the cervical mucosa. Situated in the anterior wall of the uterus is a myoma, 15 cm. in diameter. The uterine mucosa is normal.

The appendages on both sides are perfectly normal.

Histologic Examination—The mucosa of the vaginal and cervical portions of the cervix is normal. The growth on the posterior surface of the cervix consists in large measure of fibrous tissue. It also contains a moderate amount of nonstriated muscle. Here and there in this diffuse growth are irregular deposits of uterine mucosa (Fig. 11). This in some places presents the normal picture, at other points it shows a mild grade of hypertrophy. Here and there the stroma of the mucosa shows hemorrhage.

We are dealing with a typical adenomyoma of the rectovaginal septum.



Fig. 11 (Case 3)—Adenomyoma of the rectovaginal septum. For the gross specimen see Figure 10. The tissue was very difficult to cut, hence the imperfect section. The glands of the growth are surrounded by the characteristic stroma.

CASE 4 (Septum Case 12)—*Adenomyoma of the rectovaginal septum* (Figs 12 and 13)

History (Gyn. No. 24585)—B. L., aged 25, admitted to the Johns Hopkins Hospital, Jan. 21, 1919, had had a dilatation and curettage at the Church Home and Infirmary following a miscarriage in June, 1910. On Oct. 28, 1911, she was admitted to the Johns Hopkins Hospital, and a diagnosis of chronic pelvic inflammation was made. I performed a dilatation and curettage, removed the right tube, the left tube and ovary and appendix. Laboratory examination (Gyn. Path. No. 16635) revealed acute endometritis, and (Gyn. Path. No. 16625) a double pyosalpinx, a relatively normal appendix, a cystic left ovary. There was nothing in the clinical history at that time to indicate adenomyoma.

The patient began to menstruate at 13, and was regular. Since the operation in 1911, the periods had occurred at intervals of from fifteen to twenty-one days and had lasted from six to seven days. She formerly had little menstrual pain, but for the last year the discomfort had been growing worse. The pain usually started when the period commenced, it might last for a couple of days. It was dragging, dull-aching in character, and she also had pain in the back. Her last menstrual period occurred after her admission to the hospital. There had been no intermenstrual bleeding except on one occasion, a year before, after severe exertion. There was a slight leukorrhea just before and after the period. The patient had been married two years and

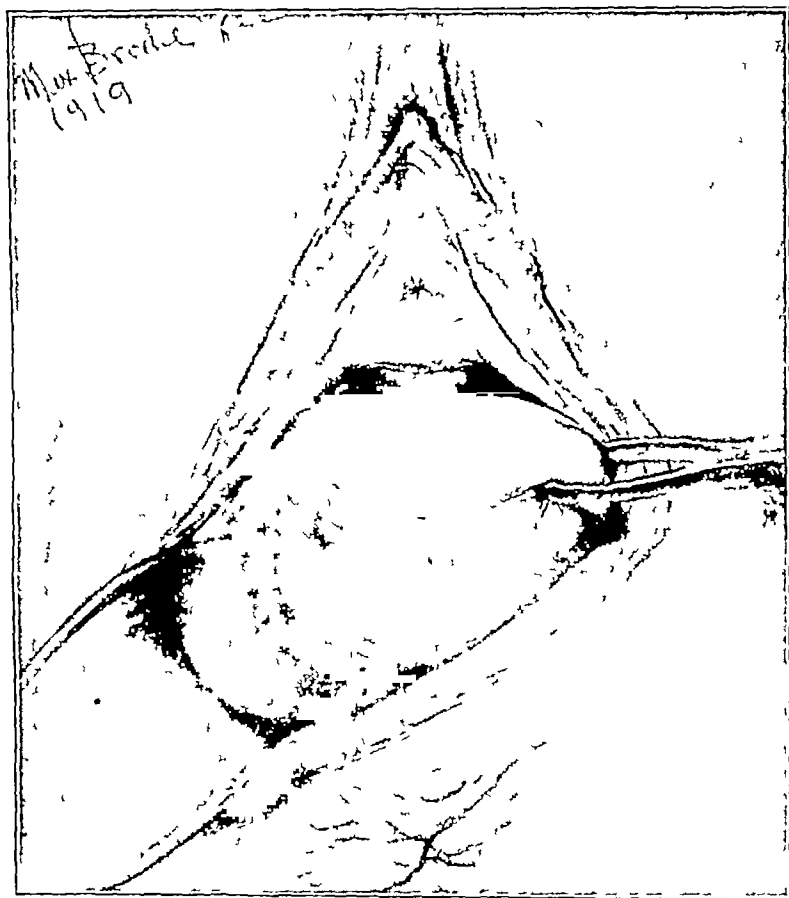


Fig. 12 (Case 4)—Adenomyoma low down in the rectovaginal septum. The cervix has been drawn strongly to the left. On the posterior surface high up are two small cysts. One stands out prominently, the other is rather hazy. Just below them, that is toward the external os, the mucosa is definitely puckered. The low position of the growth enabled us to remove it with ease through the vagina. For the histologic picture see Figure 13.

a half. She had had no children, but she had had a miscarriage at six weeks in 1910. In 1913, a small lump was felt in the vaginal wall behind the cervix. At that time it was no larger than a pinhead. It had gradually increased in size and she now had two small nodules. These were not tender.

Examination—On vaginal examination, the cervix was found to be normal in size. The body of the uterus was anteverted, and in good position. There was no thickening on either side. In the vaginal vault, slightly to the right

of the cervix, were two elastic spherical bodies each about 5 mm in diameter. They lay close together and seemed really to form part of the same nodule. They were not fixed and occasioned no discomfort. When a speculum was introduced to the side of the cervix, one saw two small bluish cysts with slight puckering of the vaginal mucosa about the center of each of these small thickenings (Fig 12).

Operation—Jan 25, 1919, I drew the cervix well over to the left, and on the right side of the vaginal vault lateral to the cervix there appeared two small areas darkish blue in color. These were incorporated in two small tumors

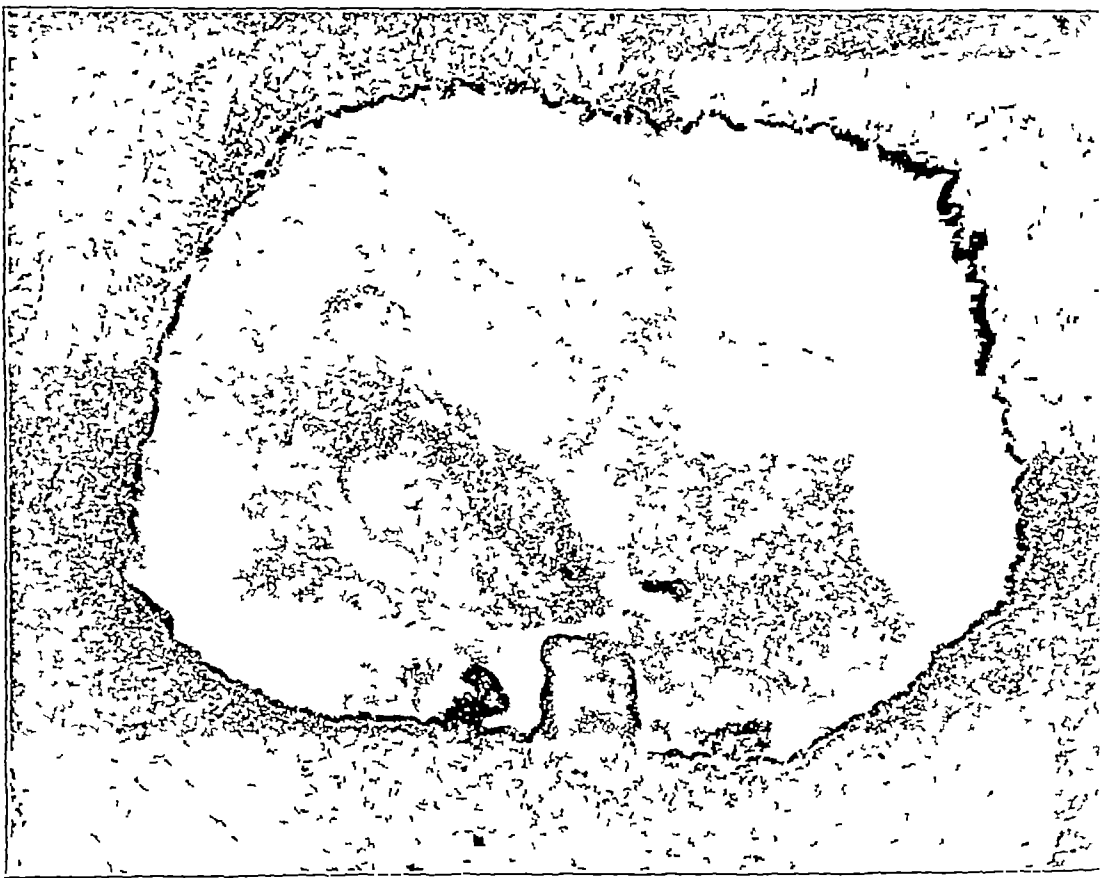


Fig 13 (Case 4)—A small cyst in an adenomyoma of the rectovaginal septum. This is one of the small cysts noted in Figure 12. It is lined with one layer of cylindric epithelium of the body type, and extending into the cavity are several small projections. The cyst contained blood and some exfoliated epithelium. At some points, the cyst epithelium lay directly on the underlying muscle, in other places it was separated from the muscle by a definite stroma.

lying deep beneath the vaginal mucous membrane. I made an elliptical incision including these two small tumors. They were removed without any difficulty and the vaginal incision closed. The patient was discharged, February 5, in good condition.

Examination of Specimen (Gyn Path No 24652)—The larger cyst reaches a diameter of 6 by 4 mm. Both cysts are surrounded by a definite layer of muscle arranged circularly. The cysts are lined by one layer of cylindric epithelium which is somewhat folded. In one of the cysts are definite projections (Fig 13). Both cysts contained blood and in the underlying stroma and muscle are quantities of yellowish brown pigment.

This was undoubtedly another adenomyoma. It was situated much lower down than usual and we were accordingly able to remove it with the minimal amount of difficulty.

CASE 5 (Septum Case 13) — *Adenomyoma of the rectovaginal septum* (Figs 14 and 15)

History (Gyn No 24864) — A A, aged 26, was admitted to the Johns Hopkins Hospital, May 2, 1919, complaining of bearing down pains in the pelvis and of backache. The patient's mother died of some form of cancer. Menstruation began at 13, was regular and lasted from three to four days. She had pain for the first day, cramplike in character. There was no intermenstrual bleeding. The patient has been married seven years. She has had

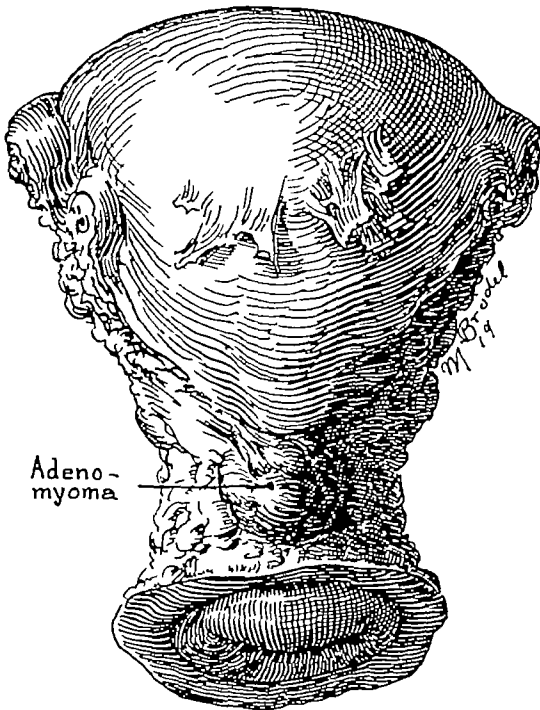


Fig 14 (Case 5) — Adenomyoma of the rectovaginal septum. Attached to the posterior surface of the uterus are a few adhesions. Springing from the posterior surface of the cervix below the peritoneal attachment is a well defined nodule, 2 by 1 cm. For the histologic picture of this nodule see Figure 15.

one child. About a year ago she began to have a dragging sensation in the lower abdomen, this was no worse at the periods. The symptoms had increased in severity.

Examination — The patient was a well developed woman. The outlet was relaxed, the cervix was lacerated. Behind the cervix was a nodule about 1.5 cm in diameter. This was not very tender. The uterus itself was normal in size and in good position. On the left side there was some thickening probably due to a prolapsed ovary. The patient had no hemorrhoids.

Dr H N Shaw, the resident gynecologist, immediately thought of adenomyoma of the rectovaginal septum.

Operation — May 3, under anesthesia, I confirmed Dr Shaw's impressions. On examination, I found that the rectum was attached to the nodule posterior

to the cervix. The rectal wall did not seem to be invaded but was somewhat puckered at this point.

When the abdomen was opened, a little puckered area could be seen just posterior to the cervix. The rectum here was lifted up and had become adherent to the puckered area. The picture was that of a typical early adenomyoma of the rectovaginal septum. The operation was begun by tying and cutting the round ligaments on each side. The right ovarian vessels were clamped and cut. We decided to leave the left ovary. After freeing the broad ligaments on each side, they were spread widely apart and the inner flap was split down to the region of the ureter. Both ureters were now dissected out and the



Fig. 15 (Case 5)—Adenomyoma of the rectovaginal septum. This section is from the adenomyoma springing from the posterior part of the cervix in Figure 14. The muscular tissue is very dense. Scattered throughout it are isolated glands surrounded by the characteristic stroma.

uterine vessels ligated. The dissection was now carried down far in the vaginal vault, and the vaginal veins were clamped and tied. After sufficient exposure had been obtained in this manner, the uterosacral ligaments were cut and the uterus drawn well out. The vagina was then cut across well below the nodule in the rectovaginal septum and the thickened vaginal wall was gradually dissected free from the rectum. The bowel was in no way damaged. The appendix was removed, a small drain was left in the pelvis and brought out through the vagina, and the abdominal incision closed. The patient left the table in excellent condition. She was discharged, May 25, 1919.

Examination of Specimen (Gyn Path No 24989)—The specimen consists of the uterus, right tube and ovary and appendix. The uterus is 8 cm long, 6 cm broad and 4.5 cm in its anteroposterior diameters. The anterior surface of the uterus is smooth, the posterior surface is covered by a few shaggy adhesions, but is for the most part smooth. Projecting from the posterior surface of the cervix near the internal os is a nodule 2 by 1 cm (Fig 14). This is irregular. It blends into the cervical tissue, but the line of demarcation is sharply defined. Its superficial portion invades the surrounding adipose tissue. It contains a few minute brownish areas. The vaginal portion of the cervix shows some laceration. The uterine mucosa reaches 6 mm in thickness.

The right tube is normal. The right ovary contains an unruptured corpus luteum, and the peritoneum over this area has been adherent.

Histologic Examination—The mucosa of the vaginal portion of the cervix is normal. The cervical glands present the usual appearance. The nodule projecting from the posterior surface of the cervix consists of nonstriated muscle and fibrous tissue. Scattered throughout it are small irregular islands of uterine mucosa (Fig 15). Near the point where the growth was attached to the rectum is a rather large area of mucous membrane showing the characteristic gland hypertrophy now and then noted in the mucosa of the body of the uterus.

This is a typical case of adenomyoma of the rectovaginal septum.

CASE 6 (Septum Case 14) — *Extensive adenomyoma of the rectovaginal septum, extension to the surface of the right fallopian tube, uterine mucosa on the surface of the right ovary* (Figs 16, 17, 18, 19, 20 and 21).

History (Gyn No 24887)—L. G., aged 40, white, was admitted to the Johns Hopkins Hospital, May 9, 1919, complaining of dysmenorrhea and menorrhagia.

The patient had been in the hospital in 1912 (Gyn No 18377). At that time I performed a partial resection of both ovaries, released pelvic adhesions and removed the appendix.

She was again admitted to the hospital in 1915 (Gyn No 20850). At that time Dr. Neill, the resident, incised and cauterized a Bartholin's gland abscess.

The patient's menses were fairly regular and lasted seven days. There was a very profuse flow. The last period was April 20. There was no intermenstrual bleeding. The patient had always had very severe dysmenorrhea. This had become more distressing during the last year. The most acute pain was experienced a day before the period started. During the twenty-four hours before the onset of the flow the patient was nauseated, vomited, had extreme abdominal pain and pain in the back. These symptoms were getting worse.

The patient had been married fifteen years. She had one child, fourteen years ago, and no miscarriages.

Examination—The patient was a rather delicate, undernourished, middle-aged woman. Her hemoglobin was 75 per cent, white blood cells, 11,000. The lower abdomen was prominent, due to a hard mass extending up from the pelvis and reaching to within about 4 cm of the umbilicus. The outlet was moderately relaxed and the cervix was high up in the vaginal vault. It was continuous with the abdominal tumor.

Operation—May 12, 1919, on examination under ether, the pelvis was found to contain a large mass about the size of a five-months' pregnancy. On the surface of this and also posteriorly, a hard nodule could be felt. In the rectovaginal septum on the left side was a dense indurated mass.

When the abdomen was opened, the uterus was found to be quite symmetrical and enlarged from the fundus to the cervix. The right tube was filled with fluid and was adherent to the uterus. The intestines were adherent to the posterior surface of the uterus. The culdesac was indurated, and the rectum was adherent well up on the posterior surface of the uterus. It was also firmly attached to the left broad ligament. The left tube was partly obscured by adhesions, and the left ovary was buried in adhesions. As a

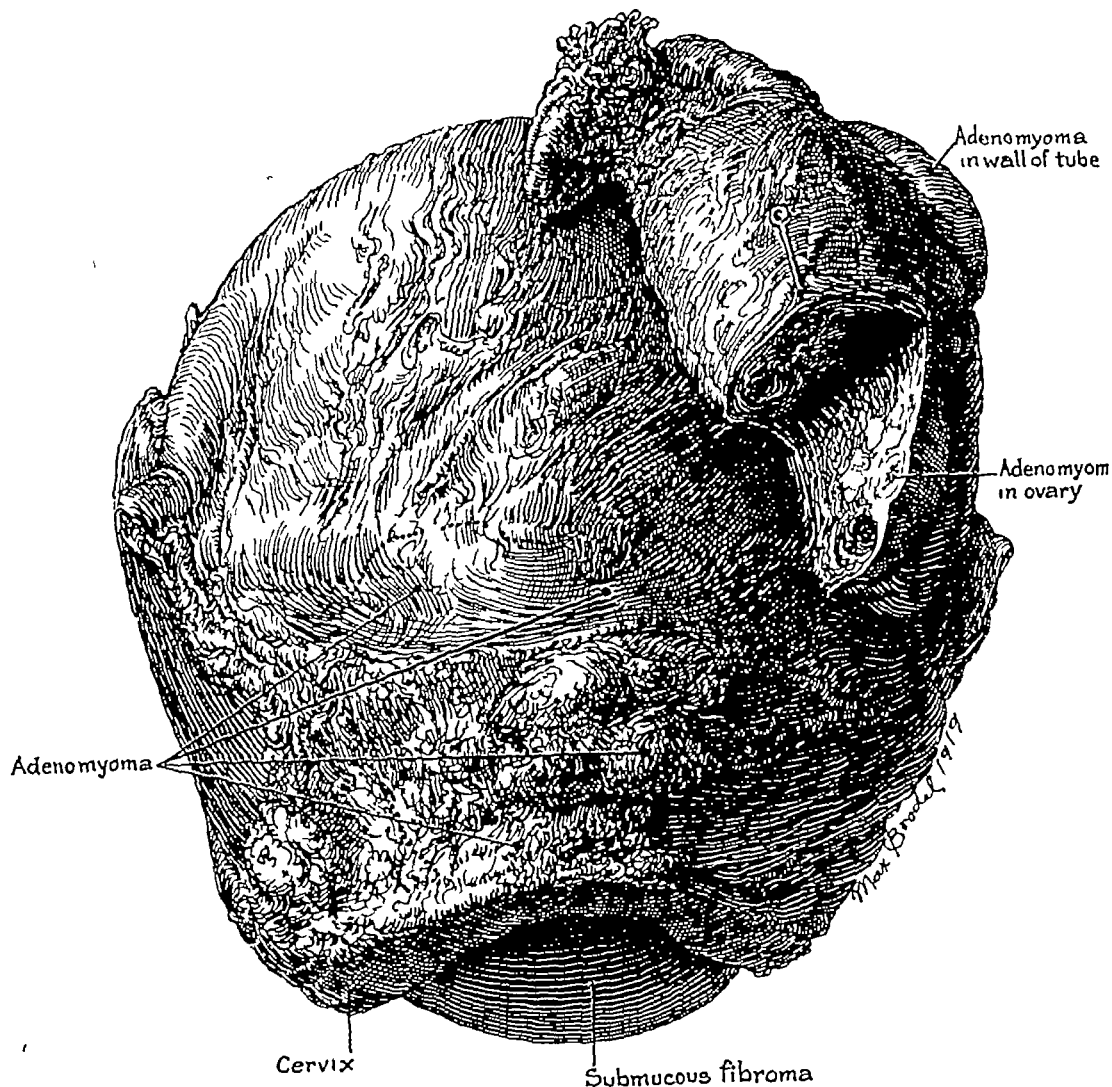


Fig 16 (Case 6) —Widespread adenomyoma of the rectovaginal septum, extension to the surface of the right ovary and tube. The supravaginally amputated uterus was 13 cm long and 11 cm broad. Its anterior surface was smooth, its posterior surface covered by adhesions. Occupying the posterior surface of the cervix and extending well up on the body of the uterus was a diffuse and hard growth. This consisted of typical adenomyoma (Figs 17, 18 and 19). The right tube and ovary formed one large solid mass, and on the surface of both tube and ovary was typical uterine mucosa (Figs 20 and 21). This is the most widespread distribution of an adenomyoma of the rectovaginal septum that I have ever seen.

matter of fact, the left tube and ovary and the sigmoid flexure formed one solid mass.

The operation was begun by separating some loops of bowel from the pelvis, then the left round ligament was cut, the left tube and ovary were clamped off at the uterus and left temporarily in place. The bladder was pushed down

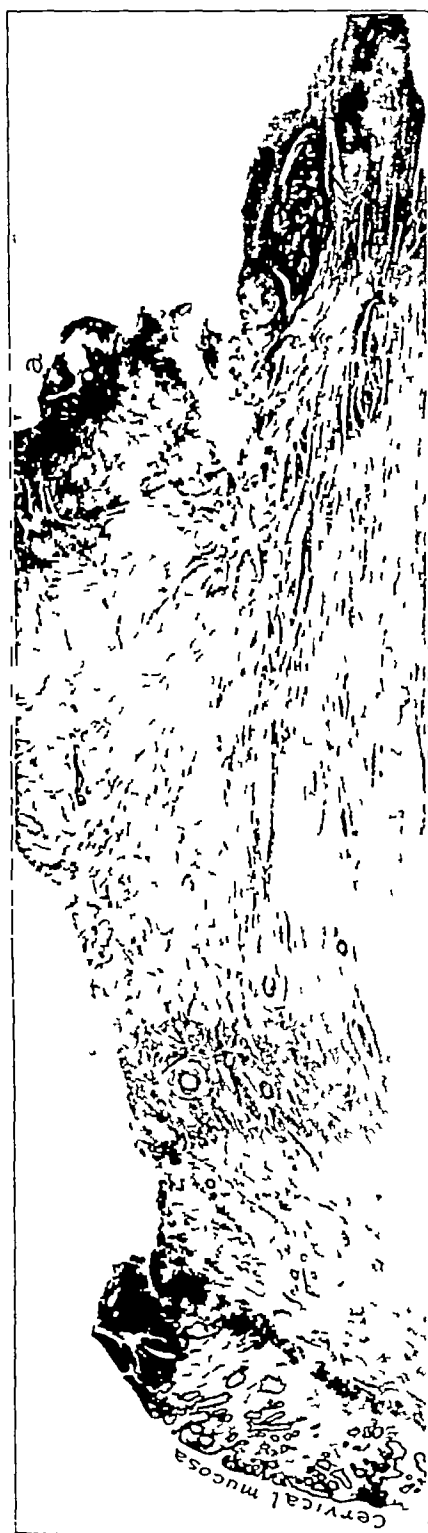


Fig 17 (Case 6) —Adenomyoma of the rectovaginal septum. This section is from the cervix of the uterus seen in Figure 16. To the left is normal cervical mucosa, to the right we see islands of uterine mucosa from the rectovaginal septum. The area *a* has been magnified and is shown in Figure 18.

and the right round ligament was cut, the right ovarian vessels were then clamped and cut. After this procedure, it was found possible to lift the uterus well up, and we then realized that without doubt we were also dealing with an adenomyoma of the rectovaginal septum. Dissection was gradually carried down on the posterior surface of the cervix as far as possible, and a supravaginal amputation performed. Better exposure could now be obtained, and the stump of the cervix was dissected free. The rectum was densely adherent to the hard mass occupying the lower and posterior part of the uterus, the posterior part of the cervix and the adjacent rectovaginal septum. During manipulation a little dark blood escaped from the rectovaginal septum. To

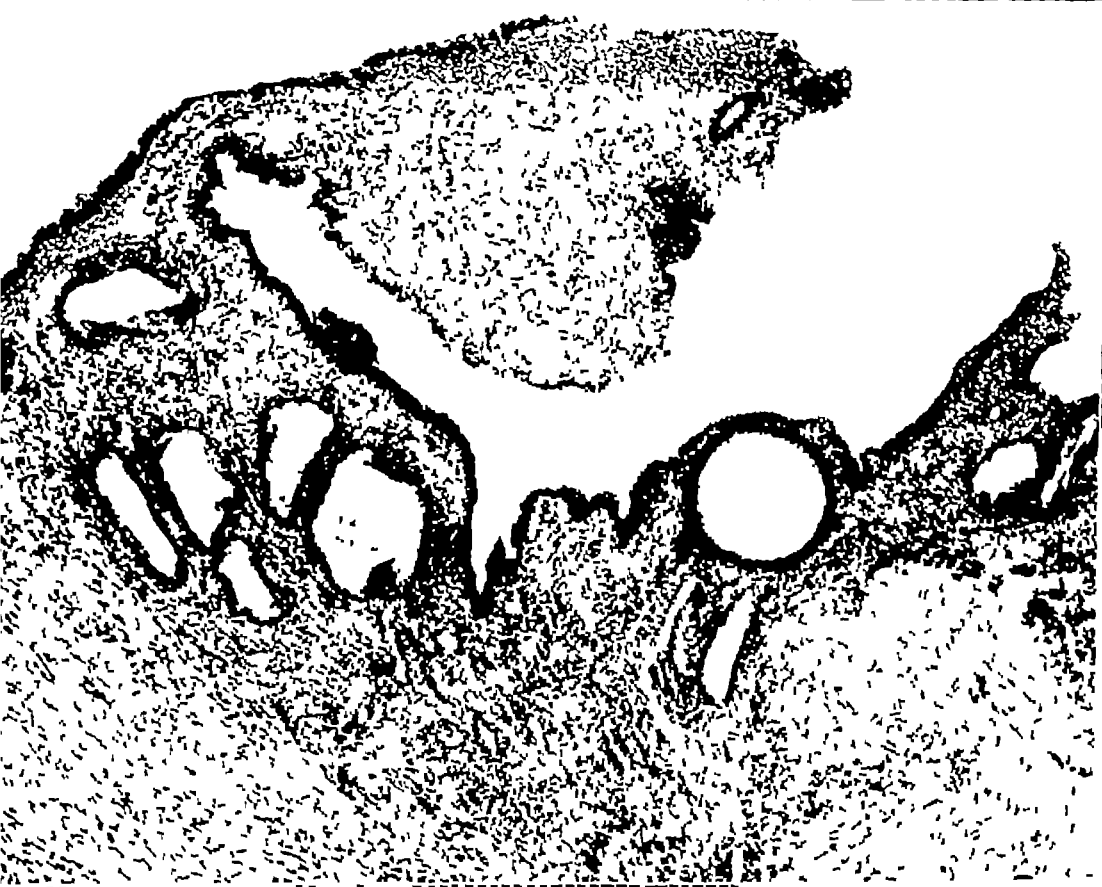


Fig 18 (Case 6) —This picture is an enlargement of the area *a* in Figure 17. One sees numerous uterine glands surrounded by the typical stroma of the mucosa. A few of the glands are dilated. In the upper part of the picture is an area of characteristic stroma covered over by one layer of cylindric epithelium.

have removed entirely the diffuse growth of the rectovaginal septum would have been an impossibility. As it was, it was one of the most difficult hysterectomies I ever attempted. The ureters were not exposed on either side, but they could be seen through the pelvic peritoneum, they were well removed from the point where the uterine vessels were controlled.

The cut edge of the vaginal mucosa was then controlled all the way round, and then the broad ligaments were obliterated as far as possible. Notwithstanding our attempts to leave a smooth surface, a small amount of raw area still remained in the culdesac. Two cigaret drains were placed in the pelvis

and brought out through the vagina. The abdomen was then closed in the usual manner. The patient lost a considerable amount of blood during the operation but left the table in good condition.

She was discharged, June 1, 1919. There was no induration in the pelvis and she felt well.

We shall watch the subsequent history in this case with a good deal of interest as some of the adenomyomatous growth was of necessity left adherent to the rectum.

Examination of Specimen (Gyn Path No 25003)—The specimen consists of the enlarged uterus with its detached cervix and of the appendages from both sides.

The supravaginally amputated uterus is 13 cm long and 11 cm in its anteroposterior diameters. The anterior surface of the uterus is smooth, the posterior surface at the fundus is covered by shaggy adhesions. The greater



Fig 19 (Case 6)—Adenomyoma of the rectovaginal septum. This is a section from the adenomyoma of the rectovaginal septum shown in Figure 16. The uterine mucosa is unusually abundant, forming fully half of the section. Even with the very low power it will be noted that many of the glands show hypertrophy.

part of the posterior surface over an area approximately 7 cm from above downward and 12 cm from side to side presents a rough and ragged appearance. This is the area that will prove to be of the greatest interest, the appearance being due to a widespread adenomyoma occupying the posterior surface of the uterus and cervix (Fig 16).

The increase in size of the uterus is in large measure due to the presence of a submucous myoma 10 cm in length. This projects into the uterine cavity from the posterior wall. The anterior wall of the uterus varies from 1.5 to 2 cm in thickness, and the mucosa from 1 to 7 mm. The mucous membrane over the surface of the submucous myoma is very thin, in most places being not over 0.5 mm thick.

The widespread raw area which occupies the greater part of the posterior surface of the uterus has a very ragged appearance. As noted from the description of the operation, this area had literally to be cut away from the rectum. On incising the raw area, one notes a coarse striation of the tissue, and at various points are small brownish specks. Histologic examination will show that this is adenomyomatous tissue.

The lower portion of the cervix was removed after the fundus had been taken away. The vaginal portion of the cervix shows some eversion of the cervical mucosa.

Right Side The tube and ovary form a conglomerate mass which has been densely adherent to the side of the uterus as well as to the surrounding structures. Notwithstanding this the fimbriated end of the tube is patent and

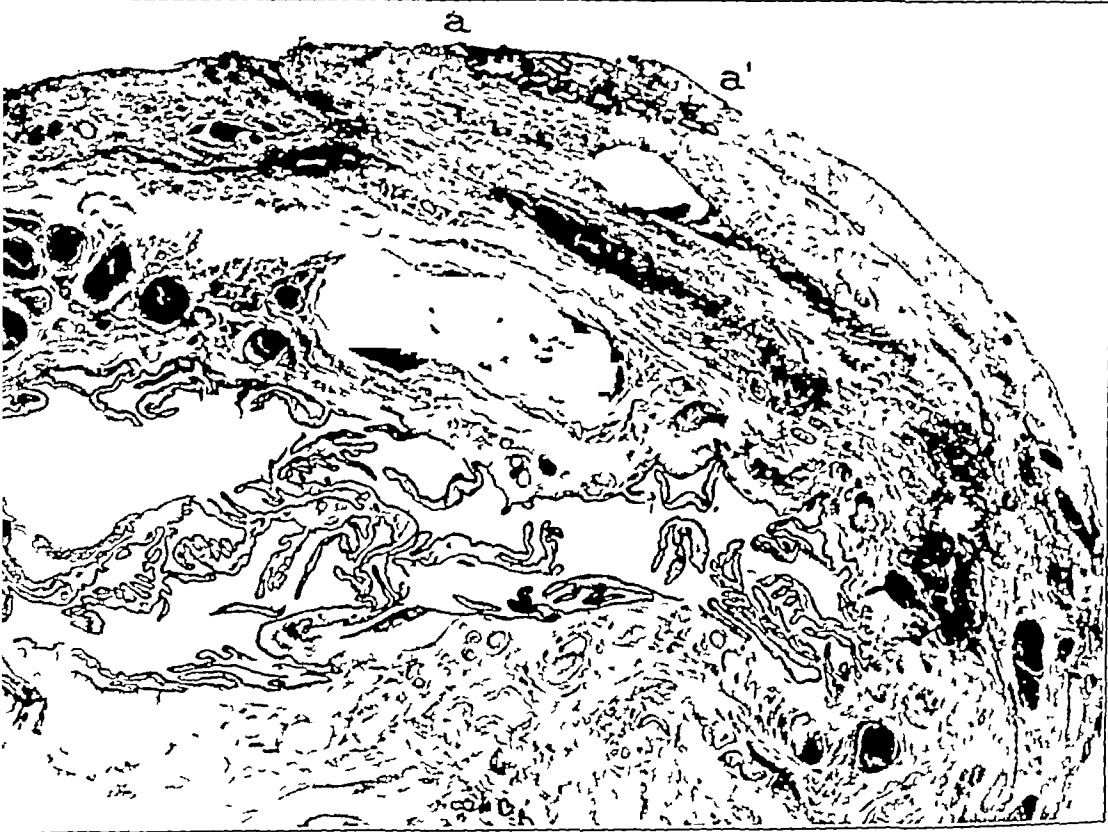


Fig 20 (Case 6)—Extension of an adenomyoma of the rectovaginal septum to the surface of the adherent fallopian tube. The gross appearance of the tube is shown in Figure 16. The folds of the tube look relatively normal. The solid black areas are blood vessels. On the surface of the tube at *a* *a'* is an area of typical uterine mucosa. It really looks as if the widespread adenomyoma of the rectovaginal septum has literally flowed over on the surface of the tube.

appears relatively normal. The tubo-ovarian mass measures 10 cm in length and at one point reaches a diameter of 5 cm. It is impossible to trace the continuity of the tube in its middle portion where it is intimately attached to the ovary and is covered by adhesions. The ovary contains at least two small corpora lutea cysts.

Left Side The appendages form an inseparable mass, 6 cm long and about 4 cm in diameter. They are embedded in adhesions, but the fimbriated end of the tube is patent.

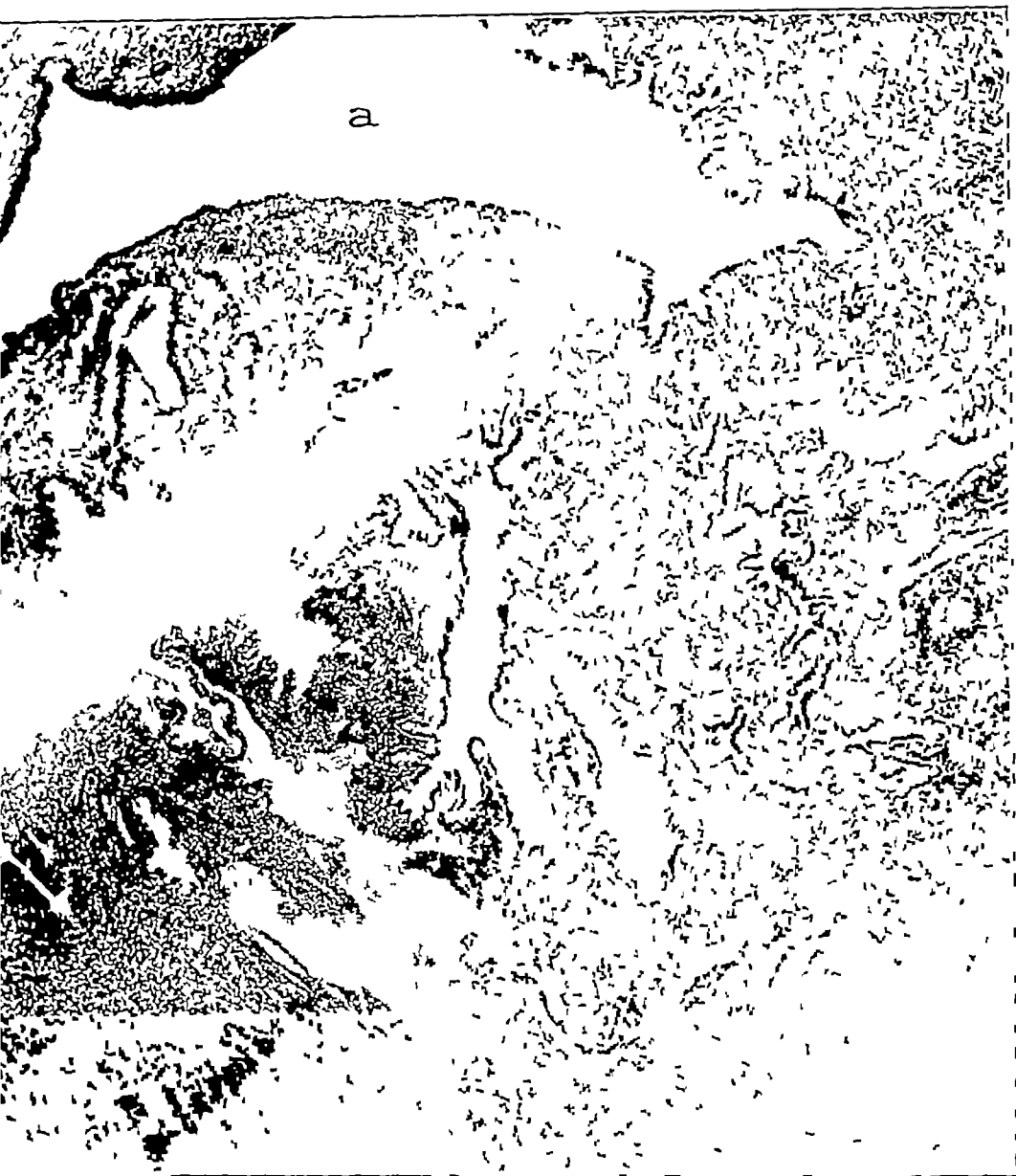


Fig 21 (Case 6) —Uterine mucosa on the surface of the ovary in a case of adenomyoma of the rectovaginal septum. For the gross appearance of the ovary see Figure 16. The miniature uterine cavity on the surface of the right ovary is represented by *a*. The lining mucosa resembles in every particular that of the body of the uterus. Some of the glands show hypertrophy. The mucosa of the adenomyoma of the rectovaginal septum seems to have overflowed to the surface of the adherent ovary. The same condition was noted on the surface of the corresponding tube (Fig 20).

Histologic Examination.—Sections from the cervical mucosa show that it is normal (Fig 17) Sections from various portions of the large raw area on the posterior surface of the body of the uterus and cervix present an amazing picture (Figs 17, 18 and 19) The tissue consists in large measure of nonstriated muscle, and scattered everywhere throughout this are tremendous areas of perfectly normal looking uterine mucosa So abundant is the mucosa in many places that it forms at least one half or two thirds of the section This mucous membrane in many places shows a tendency toward hypertrophy (Fig 19) Its stroma shows a considerable amount of hemorrhage, and here and there a gland is dilated reaching a millimeter or more in diameter This is the most widespread distribution of an adenomyoma on the posterior surface of the uterus that I have ever seen

The myoma occupying the posterior wall of the uterus and projecting into the uterine cavity shows much hyaline degeneration

Sections from the right uterine cornu show that the tube at this point is perfectly normal, but sections further out, although showing a normal mucosa, reveal typical areas of uterine mucosa on the surface of the tube (Fig 20) One gathers the impression that the uterine mucosa from the diffuse adenomyoma on the posterior surface of the cervix and uterus has overflowed upon the adherent tube

On the surface of and intimately attached to the right ovary is a miniature uterine cavity (Fig 21) The glands of its mucosa show a moderate hypertrophy Other sections from the same ovary show a diffuse adenomyoma intimately blended with the ovarian tissue, so intimately attached that no line of demarcation can be detected It must be remembered, however, that this ovary was firmly glued to and continuous with the diffuse adenomyoma occupying the posterior surface of the uterus

CASE 7 (Septum Case 15) —*Adenomyoma of the rectovaginal septum* (Figs 22 and 23)

History (Gyn No 24984) —C B, aged 36, white, entered the Johns Hopkins Hospital, June 12, 1919, complaining of pain in the left lower abdomen at the menstrual period She also had severe headaches The menses began at 13, were regular until six months ago when they appeared three times in a month, the last period was on June 7, the one previous on May 28 During the last two months the pain had been severe in the left lower abdomen She gave no history of rectal bleeding at the menstrual period

Examination —On pelvic examination, the cervix was found low in the vagina The body of the uterus had dropped back, was irregular and nodular in outline In the left side of the pelvis was a movable, cystic, rather tense mass about 8 cm in diameter

Operation —On examination under anesthesia in addition to the above findings, a small cystic mass could be felt on the right June 14, the abdomen was opened and two cysts with rather opaque looking walls were seen in the pelvis One lay up in under the left broad ligament, the other occupied the floor of the culdesac, both contained dark chocolate-colored fluid, in other words, there was a corpus luteum cyst on each side The cysts were resected and a small piece of ovary was left on both sides After removal of the cyst, there still remained a small adherent mass between the cervix and rectum, and there was no doubt that an adenomyoma of the rectovaginal septum existed The ureters were isolated, the uterus freed on all sides and the vagina cut across A small amount of adenomyomatous tissue was left adherent to the rectum Near the completion of the operation, it was found that the left tube

and ovary had a very poor blood supply, and for this reason they were removed. The appendix, which was very long, was also removed. A drain was laid in the pelvis and brought out through the vagina. The abdomen was then closed. A considerable amount of blood was lost during the operation. The patient left the table in fair condition. She was discharged, July 5, 1919, in good condition.

Examination of Specimen (Gyn Path No 25120)—The specimen consists of the uterus and of the much mutilated appendages together with the appendix.

The uterus is 11 cm long, 6 cm broad and 4 cm in its anteroposterior diameters (Fig 22). The anterior surface is smooth. The posterior surface almost to the top of the fundus is covered by adhesions. Springing from the posterior surface of the cervix is a raised hard area 2.5 by 2 cm. The tissue here is exceptionally hard, and on section it presents a brownish black appearance. It extends into the posterior cervical wall nearly 1 cm and spreads

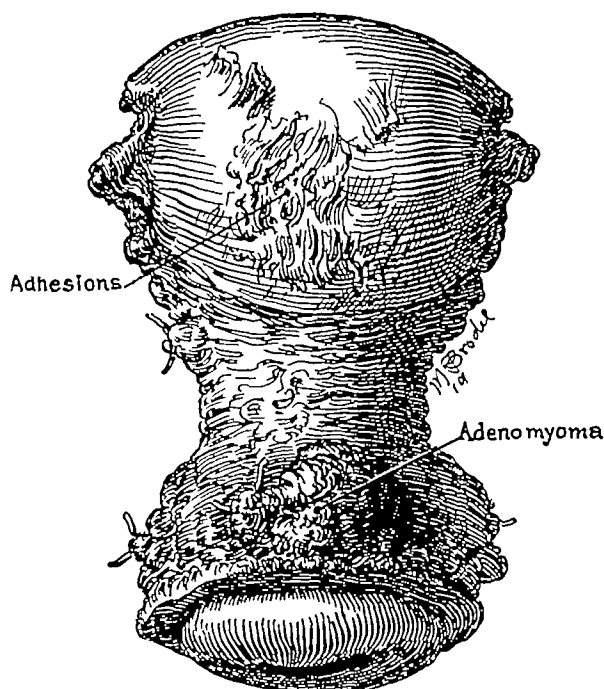


Fig 22 (Case 7)—Adenomyoma of the rectovaginal septum. The posterior surface of the fundus is partially covered by adhesions. Springing from the posterior part of the cervix near the vaginal attachment is a well defined adenomyoma 2.5 by 2 cm. For the histologic picture, see Figure 23.

out like the broad roots of a tree. It also encroaches slightly on the posterior vaginal wall. The mucosa of the vaginal portion of the cervix is somewhat everted. The mucous membrane lining the cervical canal and the cavity of the uterus presents the usual appearance.

On account of mutilation it is impossible to tell which are the right and which the left appendages. One ovary has been converted into a thin-walled cyst, 7 cm in diameter. The inner surface of this presents a dirty chocolate-colored appearance. It is a corpus luteum cyst. A portion of the other ovary is covered by dense adhesions. It contains a corpus luteum cyst, 4 cm in diameter. Accompanying the specimen is one fallopian tube which is perfectly normal. As noted from the history, one tube and part of one ovary were left

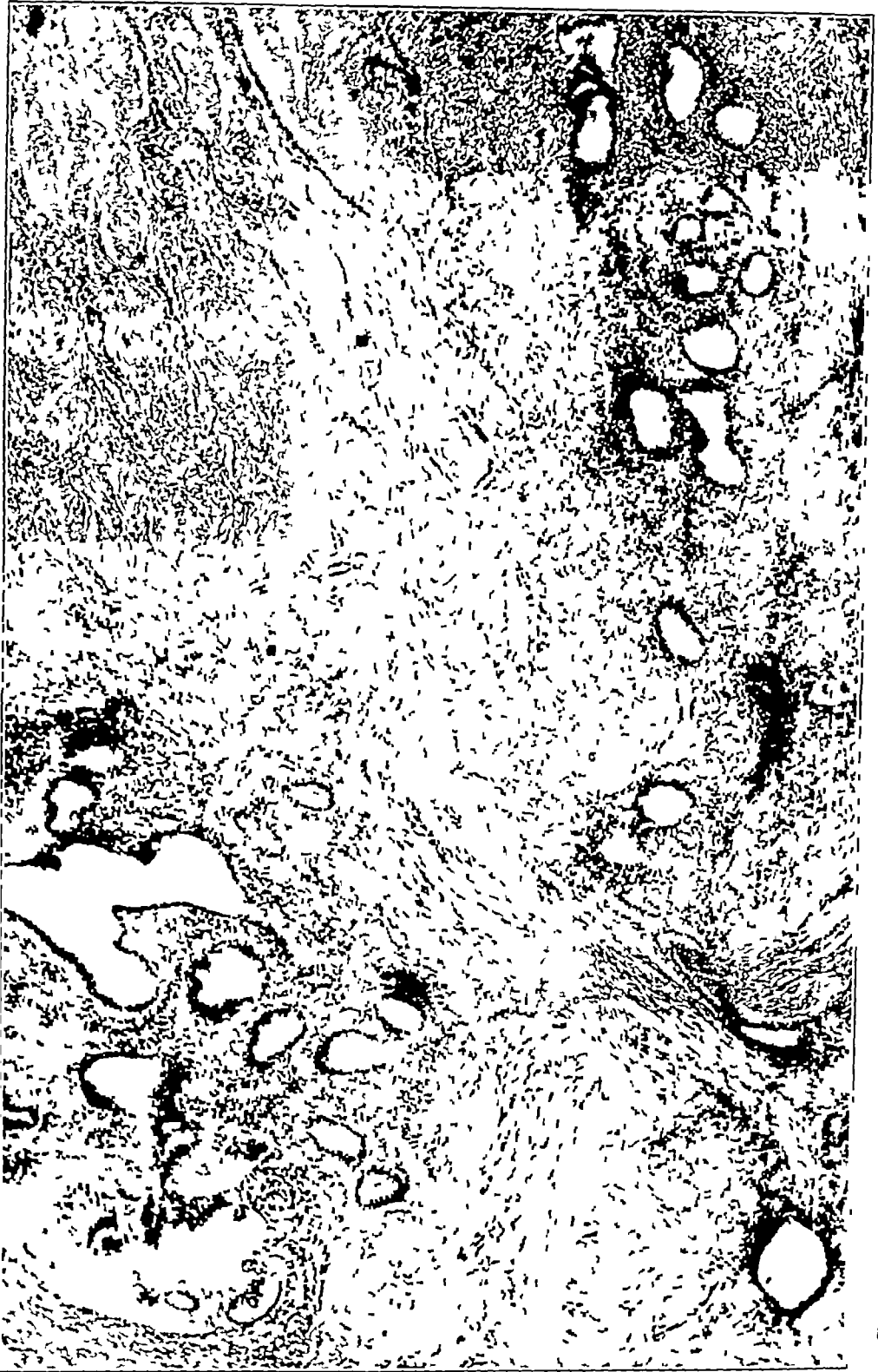


Fig. 23 (Case 7) — Adenomyoma of the rectovaginal septum. For the gross specimen, see Figure 22. The matrix of the growth is made up of nonstriated muscle and fibrous tissue. Occupying fully one third of the field are areas of typical uterine mucosa. Some of the glands are dilated. Here and there a gland lies in direct contact with the muscle.

in place We had in this case corpora lutea cysts on both sides, and these were covered by adhesions while both tubes were normal

The appendix is very hard, 9 mm in diameter The lumen of the appendix is not over 1 mm in diameter

Histologic Examination—The cervical glands present the usual appearance The mucosa lining the body of the uterus shows some small round cell infiltration in the superficial layers The growth on the posterior surface of the cervix consists of nonstriped muscle and fibrous tissue Scattered throughout it are large and small islands of uterine mucosa (Fig 23) The stroma of this mucosa shows a considerable amount of hemorrhage Here and there a uterine gland lies in direct contact with the muscle

The picture is that of a typical adenomyoma of the rectovaginal septum

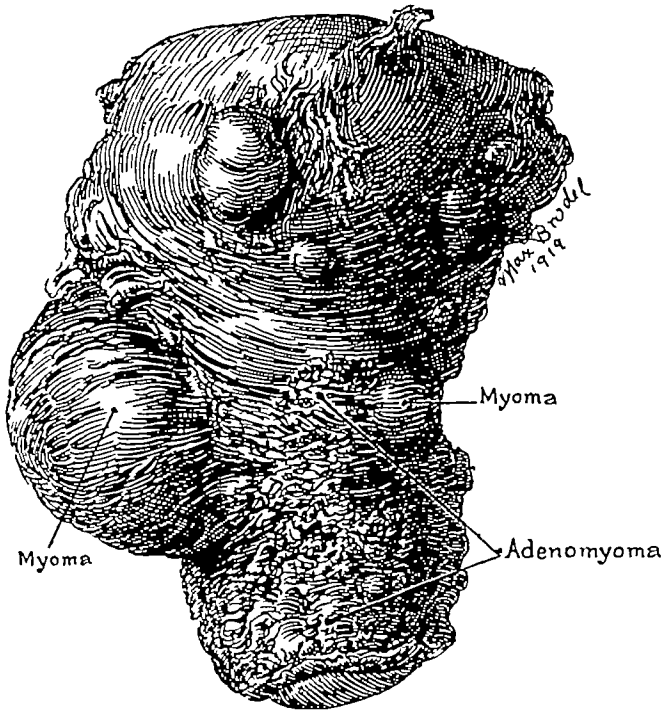


Fig 24 (Case 8)—Multiple uterine myomas adenomyoma of the rectovaginal septum The specimen is viewed from behind Scattered over the posterior surface of the uterus are several small myomas, and projecting into the left broad ligament is a myoma 3.5 by 2.5 cm Occupying the posterior part of the cervix is a rather extensive adenomyoma This was densely adherent to the rectum which had been drawn up For the histologic appearance of the adenomyoma, see Figure 25

CASE 8 (Septum Case 16)—*Adenomyoma of the rectovaginal septum, small multiple uterine myomas* (Figs 24 and 25)

History (C H I No 22465)—C W, aged 36, was referred to me by Dr Carlton M Cook, Oct 9, 1919

She began to menstruate at 14, was regular, the flow was free and lasted from six to seven days It was formerly painful for the first two days but now the pain persisted throughout the entire period and the patient had to remain in bed Her last period ended a few days ago It had persisted for ten days

Twelve years ago she had an abdominal operation, several fibroids were removed one ovary and part of the other were also taken away

The patient has been worse since she had influenza in October, 1918

Examination—The patient was admitted to the Church Home and Infirmary October 9, and operated on Nov 4, 1919 On examining this patient under anesthesia, I felt a nodule, about 1 cm in diameter, just posterior to the cervix and was instantly reminded of an adenomyoma of the rectovaginal septum On the left side was an area of thickening, approximately 2 by 3 cm As there were evidently many adhesions, a definite diagnosis could not be made

Operation and Result—I made a median incision and found a few omental adhesions on the anterior abdominal wall The left tube and ovary had been removed at a previous operation The right ovary was densely adherent to the pelvic floor and also to an epiploic appendage We decided that a removal of the uterus was indicated, more particularly as the cervix was adherent to the anterior surface of the rectum The rectum was also drawn upward We removed the uterus from left to right, amputating through the cervix and removing the left tube and ovary



Fig 25 (Case 8)—Adenomyoma of the rectovaginal septum For the gross picture, see Figure 24 The muscular growth is very dense, the glands few and far between In the upper part of the picture is a definite gland lying in direct contact with the muscle, and the surface at *a* is covered by one layer of cylindric epithelium

After removing the uterus, I took out the cervix and it was necessary literally to cut the posterior vaginal wall and the cervix away from the rectum There was just the slightest area of thickening on the anterior rectal wall

After controlling all oozing, we examined the right ureter and found it normal The left ureter could not have been located without a great deal of dissecting The appendix was curled on itself and adherent It was also removed Two drains were left in the pelvis and brought out through the vagina

The patient left the hospital in excellent condition on Nov 24, 1919

Examination of Specimen (Gyn Path No 25477)—The cervix and body of the uterus when put together give a combined length of 8 cm (Fig 24) The uterus is 6 cm broad and 4 cm in its anteroposterior diameters The anterior surface of the uterus is smooth, but nearly the entire posterior surface is covered by adhesions Projecting from the posterior surface, high up, is a pedunculated bean-shaped myoma, 15 cm. long There are also a few other minute myomas scattered over the surface of the uterus Attached to the left side of the cervix and extending into the broad ligament is a myoma,

35 by 25 cm. Projecting from the center of the cervix posteriorly is a small raised area of thickening, about 1 cm in diameter. This is where the rectum was attached to the cervix. The cavity of the uterus contains a pedunculated submucous myoma, 2 cm in diameter. The thickening noted on the posterior wall of the cervix is hard and contains a few chocolate-colored areas.

Histologic Examination—Sections from the cervix show that the mucosa is normal. The growth on the posterior surface of the cervix consists of non-striped muscle and fibrous tissue. In the outlying portions it is interesting to

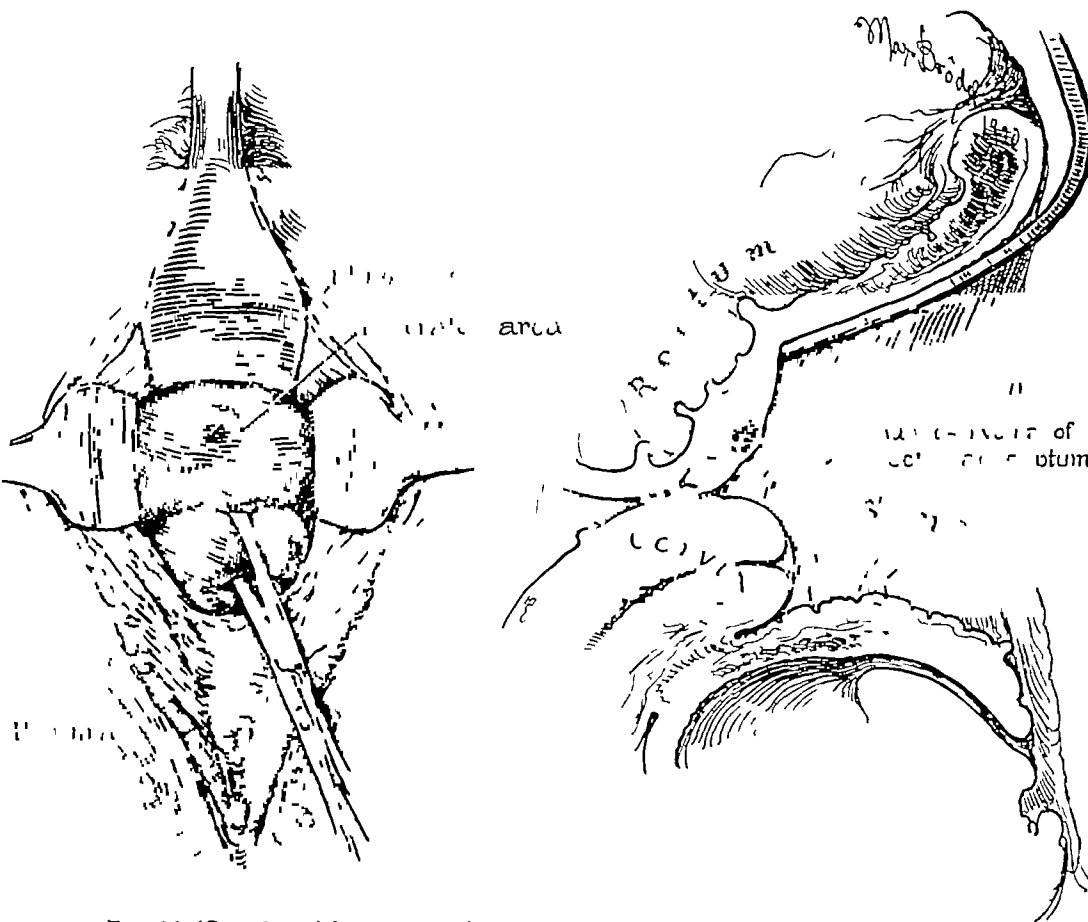


Fig 26 (Case 9)—Adenomyoma of the rectovaginal septum. The patient is shown in the knee-chest posture. Just behind the cervix and slightly to the left of the median line is a relatively globular nodule about 1.5 cm in diameter. In this nodule were two bluish black cysts, only one of which could be clearly seen. The relation of the adenomyoma to the cervix and rectum is clearly indicated in the picture to the right. Although no microscopic examination has been possible, still the diagnosis is certain.

see the manner in which the diffuse myomatous growth is gradually replacing the adipose tissue. Here and there in the diffuse growth is a uterine gland usually lying in direct contact with the muscle (Fig 25). Some of the growth has, as was noted at operation, been left attached to the rectum.

CASE 9 (Septum Case 17)—*Adenomyoma of the rectovaginal septum* (Fig 26)

History—Mrs E B H, aged 36, referred to me by Dr Arthur Wegfarth, entered the Church Home and Infirmary Nov 1, 1919 (No 22461). I had operated on this patient in 1917 for appendicitis. In August 1919, while at

dinner, she was taken with sharp, excruciating pain beneath the right costal margin, and the pain radiated to a point just beneath the right shoulder blade. She was almost drawn double. This attack was followed by nausea and vomiting, and the pain was relieved only by morphin. Since then she had had eight similar attacks. The patient had been married twenty years and had one child, nineteen years ago. She also complained of pain in the left lower abdomen.

Examination—On making a pelvic examination, under anesthesia, I found the uterus normal in size. The cervix was normal, but just posterior and a little to the left was a rather globular nodule 1.5 cm in diameter (Fig 26). This seemed fixed to the cervix posteriorly, and on inspection it was found that projecting from the vaginal vault at this point were two bluish black cysts, about 2 mm in diameter. On rectal examination, the nodule was made out much more clearly. It was directly beneath the mucous membrane, but the mucosa had not become adherent. It was a definite adenomyoma.

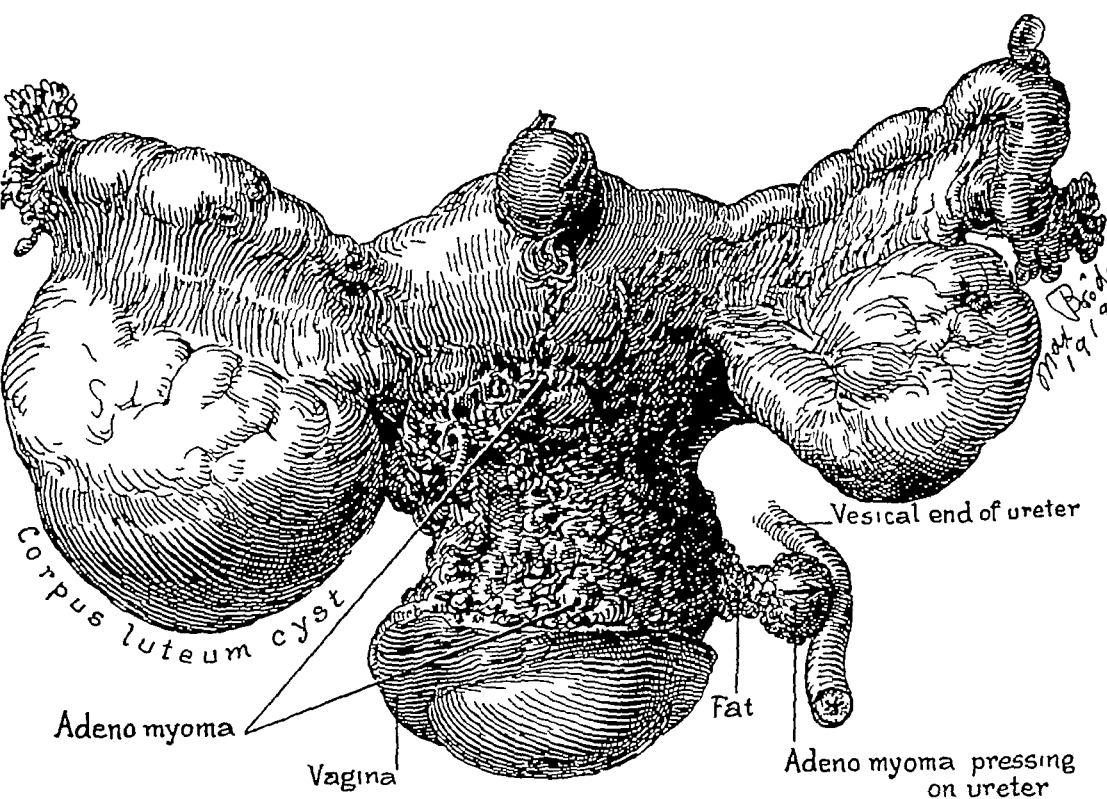


Fig 27 (Case 10)—Adenomyoma of the rectovaginal septum, discrete and independent adenomyoma in the right broad ligament pressing on and partially obstructing the ureter. Springing from the top of the uterus is a small myoma, and attached to the posterior surface of the uterus are a few adhesions. Occupying the posterior part of the cervix and extending upward is a diffuse adenomyoma. The right tube and ovary are normal. The left tube is normal but the ovary contains a corpus luteum cyst. In the right broad ligament is a small discrete nodule pressing on the right ureter. It is also an adenomyoma. For the histologic picture of the adenomyoma of the rectovaginal septum, see Figure 28, for that of the broad ligament nodule, Figure 29.

Operation and Result—Nov 4, 1919, I operated and as the patient was not complaining sufficiently of the pelvic condition, and as she had gallstones, I let the adenomyoma alone. I made a right rectus incision and exposed the gallbladder which contained a large number of small stones, the greater number of which formed two conglomerate masses, each about 1.5 cm in diameter. Some of the smaller stones were in the cystic duct. We removed the stones

and drained the gallbladder. The patient was discharged much relieved, Nov 29, 1919.

A few weeks later she developed a pelvic abscess which opened spontaneously into the vagina, and since then she has been perfectly comfortable. It may be necessary to remove the adenomyoma at a later date.

CASE 10 (Septum Case 18)—*Adenomyoma of the rectovaginal septum, discrete adenomyoma in the right broad ligament pressing on and partially obstructing the right ureter* (Figs 27, 28 and 29)

History—Miss R. M., aged 42, was referred to me by Dr. Christian Deetjen on Feb 27, 1919, complaining of pain in the left lower abdomen. This had been more or less constant for the last ten years and had been severe for four years. The patient had pneumonia ten years ago followed by empyema. She was admitted to the Church Home and Infirmary, Oct 20, 1919 (No 22402).



Fig 28 (Case 10)—Adenomyoma of the rectovaginal septum. The gross specimen is shown in Figure 27. Some of the glands are surrounded by the characteristic stroma, others lie in direct contact with the muscle.

At that time a small cyst could be felt in the left side of the pelvis. Dr. Hiram Fried, the resident, felt that there might be some trouble with the ureters and suggested their catheterization. A distinct narrowing was felt on the right side not far distant from the bladder. Dr. Guy L. Hunner confirmed this finding. The right ureter was dilated on several occasions, and we finally operated on November 8.

Operation and Result—On opening the abdomen, I found a corpus luteum cyst 4 cm in diameter, on the left side. This was somewhat adherent.

The rectum had grown fast to the posterior surface of the cervix and at this point the tissues presented a yellowish brown, rusty appearance. It was perfectly evident that we were dealing with an adenomyoma. We performed



Fig 29 (Case 10)—Discrete adenomyoma of the right broad ligament pressing on and partially obstructing the ureter. For the appearance at operation see Figure 27. At the left, where this nodule was attached to the right side of the cervix, most of the tissue consists of fat. As we pass toward the right the adipose tissue is found to be replaced in part by connective tissue. At the extreme right the tissue consists of nonstriated muscle and fibrous tissue, and scattered throughout it are a moderate number of glands resembling those of the uterine mucosa.

a complete abdominal hysterectomy The posterior vaginal wall separated from the rectum with some difficulty, but after removal of the uterus and upper vagina the bowel showed only a slight thickening The rectovaginal growth had extended out into the right broad ligament After its removal we could still feel a nodule far out in the broad ligament This was 1 cm in diameter, encroached markedly on the right ureter and had given rise to the obstruction that had been noted by Dr Fried in his catheterization of this ureter (Fig 27) I dissected out the ureter, drew it to one side and removed the nodule. Two drains were left in the pelvis and brought out through the vagina

The patient had an uneventful convalescence and was discharged Nov 30, 1919

Examination of Specimen (Gyn Path No 25486)—The uterus is 7 cm long, 4 cm broad and 3 cm in its anteroposterior diameter Anteriorly it is smooth The posterior surface is covered by adhesions At the fundus posteriorly is a myoma, 1.5 cm in diameter, and below this a minute myoma Springing from the posterior surface of the cervix is a nodular thickening, 1.5 cm in diameter, and extending off from this point is the nodule that was pressing on the right ureter The uterine walls vary from 1 to 1.5 cm in thickness, and in the fundus the muscle presents a very coarsely striated appearance reminding one somewhat of an adenomyoma The uterine mucosa is rather thin

Right Side The tube and ovary are normal

Left Side The ovary contains a corpus luteum cyst, 3 cm. in diameter The ovary is covered by a few adhesions

Histologic Examination—The vaginal portion of the cervix presents the usual appearance The cervical mucosa is gathered into folds and tends to form small polyp. A few of the glands are dilated, but the cervical mucosa as a whole is relatively normal

The section from the growth on the posterior surface of the cervix contains a young myoma, 3 mm in diameter The diffuse growth consists of nonstriated muscle and fibrous tissue Scattered throughout it are small areas of uterine mucosa (Fig 28) Few of these areas contain more than two uterine glands accompanied by the characteristic stroma Here and there is a dilated gland

The nodule from the right broad ligament, the one that was pressing on the right ureter, consists for the most part of adipose tissue (Fig 29) Scattered throughout the fat are a good many large blood vessels and passing off from these are young strands of connective tissue which tend to separate the individual fat globules from one another The outer end of the growth consists of an irregular mass of fibrous tissue and nonstriated muscle This fibromuscular mass sends prolongations into the surrounding fat and in the nodule itself some fat still persists Scattered throughout the muscular tissue are uterine glands occurring singly or in groups When in groups, they are surrounded by the characteristic stroma which shows some hemorrhage When singly, they lie in direct contact with the muscle Some of the glands are dilated

This is a case of adenomyoma of the rectovaginal septum There is also a discrete adenomyoma apparently independent of the uterus and pressing on the right ureter

The preceding cases have come under my individual care The following case of adenomyoma of the rectovaginal septum is a rather advanced one and is well worth recording The operation was per-

formed at the Hebrew Hospital by Dr Alfred Ullman, and the specimen was sent to me for examination. The history was furnished me by Dr E H Teeter.

CASE 11—*Adenomyoma of the rectovaginal septum*

History—M H, aged 46, was admitted to the Hebrew Hospital, April 24, 1919, complained of bleeding for nine weeks, and that she felt very sore and tired all over. She had not had any previous illness. Her menses began at 13, were regular, and usually lasted from seven to nine days. The flow was always excessive and was accompanied by pain in the left lower abdomen for three days. In June, 1918, her menses stopped for three months and then there was a little bleeding for a couple of days. The bleeding soon returned and had persisted for the last nine weeks. It had been very severe. On vaginal

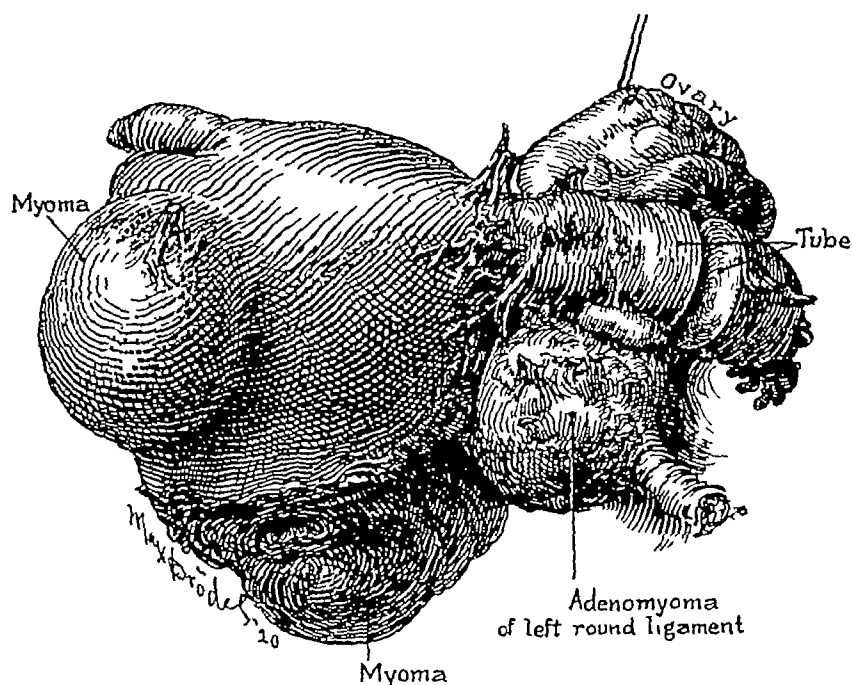


Fig. 30 (Case 12)—Adenomyoma of the left round ligament. The uterus contains several small discrete myomas. The left round ligament near its uterine attachment contains a spherical myoma, 1.5 cm. in diameter. This was adherent to the tube at its inner end. Lying between the round ligament nodule and the tube and adherent to both was a loop of small bowel. The left tube is unusually thick. Its fimbriated end is constricted but open. The tube on histologic examination showed slight inflammation. The ovary contained a corpus luteum. It was slightly adherent. For the low power picture of the adenomyoma of the round ligament, see Figure 31, for the higher power, Figure 32.

examination, April 25, Dr Teeter made the following note: "Vaginal outlet somewhat relaxed, cervix normal. The uterus and cervix are tied hard and fast and cannot be moved. The uterus itself is normal in size. Just posterior to the cervix is a growth in the vaginal vault causing puckering of the vaginal mucosa. This growth is hard and is glued fast to the rectum. On rectal examination, the mass is found to be adherent to the rectum, but the growth does not involve the rectal mucosa."

There was a profuse bloody discharge from the uterus and Dr Teeter at once made a diagnosis of adenomyoma of the rectovaginal septum.

A complete abdominal hysterectomy was performed by Dr Alfred Ullman on April 26, and the patient was discharged May 20

Examination of Specimen (Gyn Path No 25513)—The uterus is 9 cm long, 6 cm broad and 5 cm in its anteroposterior diameters. The anterior surface is smooth as is also the posterior surface. Just anterior to the insertion of the right tube is a myoma, 6 mm in diameter.

Springing from the posterior surface of the cervix and extending over to the right side and also involving the posterior vaginal wall is a hard, irregular



Fig. 31 (Case 12)—Adenomyoma of the round ligament. This is a low power photomicrograph of the round ligament nodule seen in Figure 30. Nearly one half of the tissue consists of islands of perfectly normal uterine mucosa. For the high power see Figure 32.

growth, 4.5 cm broad and 2.5 cm from above downward. It is exceedingly firm and where it involves the vagina are five or six dark brown areas of discoloration. These vary from 1 to 2 mm in diameter. On section, the growth reminds one of myomatous tissue and scattered throughout it are a few irregular cavities filled with a yellowish brown or yellow material. The cavity of the uterus looks normal.

Histologic Examination—Sections through the vaginal portion of the cervix and also through the adjoining vaginal wall reveal a normal mucosa. Beneath the vaginal mucosa the dense stroma contains isolated uterine glands. The small chocolate-colored cysts noted beneath the vaginal mucosa are filled with blood. They are lined with one layer of cylindric epithelium, and projecting into one of the cysts is a small knoblike elevation of typical stroma of the endometrium of the body of the uterus. Some of these cysts lie in direct contact with the surrounding muscular and fibrous tissue, others are separated by a definite endometrial stroma.

The growth on the posterior surface of the cervix and involving the posterior vaginal wall consists of nonstriped muscle and fibrous tissue. Here and there small areas of adipose tissue have been enveloped. Scattered throughout the growth are isolated uterine glands and groups of glands. Nearly all of these glands are surrounded by the characteristic stroma, and some of them are filled with blood.

The case is one of adenomyoma of the rectovaginal septum. It is in just such a case that we would later expect to find vaginal polyp_i had the operation been delayed for a year or two.

ADENOMYOMA OF THE UTERINE HORN OR FALLOPIAN TUBE

In addition to the diffuse adenomyoma of the uterus, one finds another variety of adenomyoma in this organ. These are the small adenomyomatous nodules noted in one or both uterine horns. They vary from a few millimeters to about 2 cm in size and are often associated with an old inflammatory process in the tubes. These growths usually contain many isolated glands embedded in nonstriped muscle and inflammatory tissue. The glands usually lie in direct contact with the muscle and are devoid of the characteristic stroma. Adenomyoma of the uterine horn can, as a rule, hardly be looked on as a distinct clinical entity, but rather, I think, as part of the end-result of a mild inflammatory process.

In a case (Gyn-Path No 25515) in which we had a bicornate uterus, and a most extensive adenomyoma of the right cornu, the left tube 2 cm beyond the uterine horn was 1 cm in diameter. On histologic examination, it was found to be the seat of an adenomyoma. Some of the glands lay in direct contact with the muscle, others were surrounded by the typical stroma of the uterine mucosa. I know of no other tube presenting such a picture.

ADENOMYOMA OF THE ROUND LIGAMENT ⁴

In 1896, it fell to my lot to record the first growth of this character. Since then quite a number have been noted. Somewhere along the course of the round ligament, usually near the external ring, a nodule

⁴ Cullen, T. S. Adenomyoma of the Round Ligament, Bull. Johns Hopkins Hosp. 7 112 (May-June) 1896, Further Remarks on Adenomyoma of the Round Ligament, Bull. Johns Hopkins Hosp. 9 142 (June) 1898, Adenomyoma of the Round Ligament, and Incarcerated Omentum in an Inguinal Hernia, Together Forming One Tumor, Surg., Gynec. & Obst. 22 258 (March) 1916.

one or more centimeters in diameter is detected. On going carefully into the history, it will be noted that this growth swells perceptibly at the period. One patient was sent to me on the assumption that a hernia existed, but even in this case in the history it was recorded that the swelling was more painful and more prominent at the period.

With the gradual increase in size of the nodule it may become intimately blended with the fascia. In my second case the diagnosis was easily confirmed at operation, even before any microscopic examination had been made. The surrounding fascia had imbibed a large amount of golden yellow pigment—the remnant of old menstrual blood.

Some of these growths can be removed very readily, others, however, in time may become so intimately blended with the surrounding structures that they must be literally cut away. On histologic examination, they are found to be made up of nonstriped muscle, fibrous tissue, and the characteristic uterine glands. Strands of fibrous tissue and nonstriped muscle spread out into the surrounding adipose tissue.

Just lately (April, 1920) we have encountered another case of adenomyoma of the round ligament in our clinic in the Johns Hopkins Hospital (Fig 30).

CASE 12 (Gyn No 25776)—History—E. S., aged 36, white, was admitted to the Johns Hopkins Hospital on April 1, 1920, complaining of dysmenorrhea and of bleeding between periods. She had been married four years, but had had no children.

Examination—On pelvic examination, the outlet was found to be relatively intact. Protruding from the cervix was a small polyp. The body of the uterus was in retroposition, was irregular and apparently contained five or six small myomatous nodules. High up in the left vaginal fornix was a mass, 2 or 3 cm in diameter.

Operation and Result—April 3, 1920, Dr. Leo Brady operated and found the uterus in retroposition. It contained several small myomas. In the left round ligament near the uterus was a nodule nearly 2 cm in diameter. The tube was adherent to this and also to a loop of small bowel. The right appendages were free. After the loop of bowel had been freed, a supravaginal hysterectomy was performed. The patient made a satisfactory recovery except for a slight elevation of temperature during the first week following operation when there was a friction rub. This was thought to be due probably to a lighting up of an old pleurisy. She was discharged in good condition on April 21, 1920.

Examination of Specimen (Gyn Path No 25850)—The uterus, which had been amputated through the cervix, measures 5 cm in length, 5 cm in breadth and 4 cm in its anteroposterior diameters. It contains several interstitial myomas. In the left round ligament near the uterus is a spherical nodule 1.5 cm in diameter (Fig 30). This is partly covered by adhesions. The left tube reaches a diameter of 1 cm. Its fimbriated end is constricted but open. The ovary is normal in size. It contains a corpus luteum and is partly covered by adhesions.

Histologic Examination—This shows that the nodule in the left round ligament is riddled with large islands of typical uterine mucosa (Figs 31 and 32).

UTERINE MUCOSA IN THE OVARY

In 1898 my colleague, Dr William Wood Russell, reported a case in which the ovary, although showing little increase in size, contained large islands of uterine mucosa. The report of this case was published



Fig. 32 (Case 12)—Adenomyoma of the round ligament. For the gross appearance see Figure 30, and for the low power picture Figure 31. The round ligament nodule consists of myomatous tissue. It contains large quantities of normal uterine mucosa.

in detail in the *Bulletin of Johns Hopkins Hospital* for that year, and the article is freely illustrated.

Within the last year Dr Charles Norris of Philadelphia sent me a section of a relatively small ovary containing a large island of normal uterine mucosa (Figs 33 and 34).

Dr DeWitt B Casler, of our department, at the 1919 meeting of the American Gynecological Society reported a unique case which has a definite bearing on this subject

The patient, a trained nurse, 38 years of age, had had excessive periods for one year. On examination the uterus was found to be three times its usual size. Hysterectomy was performed. The increase in size was due to a diffuse myomatous thickening, and scattered throughout this diffuse growth were quantities of stroma identical with that of the uterine mucosa. This stroma, however, contained no glands. The tumor resembled in every particular the picture of an ordinary adenomyoma of the uterus save for the fact that the glands were missing from the stroma.

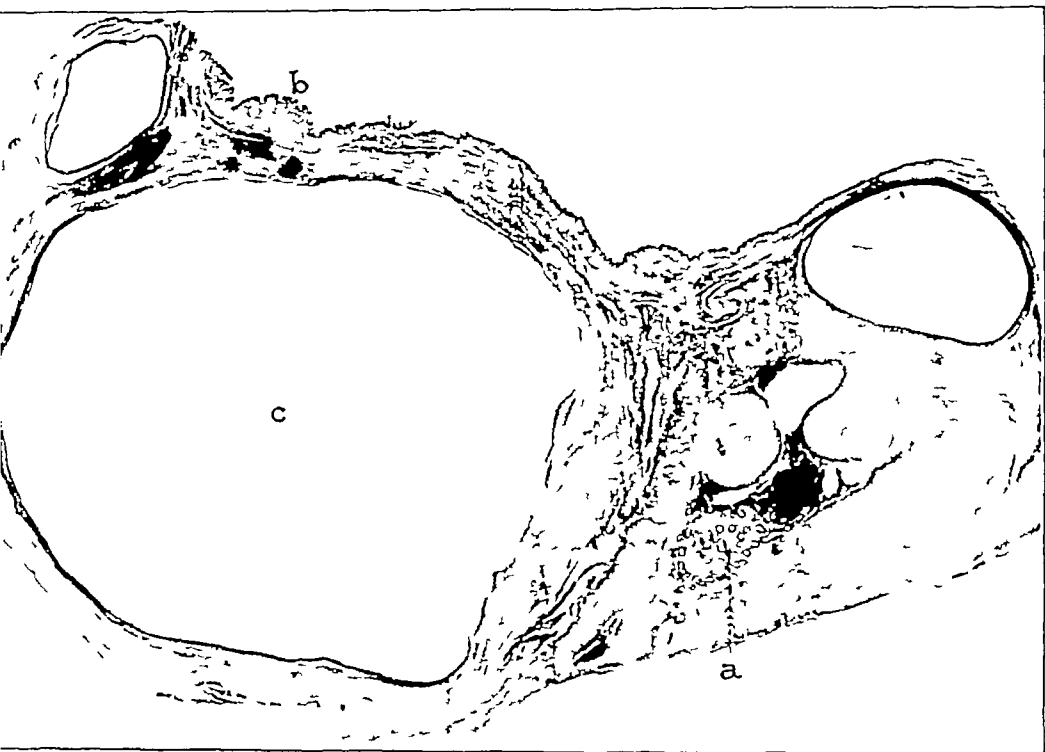


Fig 33—An ovary containing uterine mucosa. This is a very low power photomicrograph of a section through an entire ovary that was little enlarged. It was sent me by Dr Charles Norris of Philadelphia. On the left is a relatively small cyst, *c*. At *a* in the substance of the ovary is a large area of typical uterine mucosa. This is connected with an irregular cyst cavity. On the upper edge of the section is normal tubal mucosa, *b*. The tubes have evidently been intimately adherent to the ovary. In Figure 34 one sees a higher magnification of the mucosa.

This patient after the complete hysterectomy still continued to menstruate regularly through the vaginal vault. A vaginal examination about three and one-half years after the hysterectomy revealed the fact that the ovary which had been left was perfectly normal in size. A little later it commenced to grow larger and when the abdomen was opened four years after the hysterectomy this ovary was the size of a medium-sized grape fruit.

On histologic examination great quantities of typical uterine mucosa were found scattered throughout the ovarian tumor thus clearly explaining why the

patient had continued to menstruate without any uterus. The ovary contained all the essential elements, normal ova, and practically normal uterine mucosa, and the small tract left where the uterus had been removed supplied the necessary avenue along which the menstrual flow escaped.

In the following case, in which the uterus was about three times enlarged as a result of interstitial and submucous myomas and in which the appendages were glued together by adhesions, the right ovary contained small areas of typical uterine mucosa.



Fig. 34—Uterine mucosa in the ovary. This specimen was sent me by Dr. Charles Norris of Philadelphia. For the low power picture, see Figure 33. The area of mucosa is sharply defined and consists of typical uterine mucosa embedded in the substance of the ovary.

CASE 13—*A myomatous uterus with adherent appendages on the right side, and on the left a small ovarian cyst containing uterine mucosa in its walls* (Figs. 35 and 36)

Examination of Specimen (Gyn. Path. No. 22505, Sept. 19, 1916)—The specimen consists of the supravaginally amputated myomatous uterus together with the appendages (Fig. 35).

The portion of the uterus present is 10 cm. long, 10 cm. broad and 10 cm. in its anteroposterior diameter. At the fundus anteriorly are a few omental adhesions. Occupying the posterior wall of the uterus is a myoma 8 cm. in diameter. Scattered throughout the anterior wall are several nodules, the



FIG. 35 (Case 13).—A myomatous uterus with adherent appendages on the right side and on the left a small ovarian cyst containing uterine mucosa in its wall. The uterus contains subperitoneal, intersutural and submucous myomas. The left ovary contains a cyst lined in part by uterine mucosa (Fig. 16).

largest 3 cm in diameter. Projecting into and filling the cavity of the uterus is a myoma, 4 cm long and 2.5 cm broad.

Right Side The tube is 8 cm in length and varies from 8 to 10 mm in diameter. Its fimbriated end is free. The ovary is 7 cm in length. It reaches a thickness of 2.5 cm. Attached to the outer end is a moderate amount of fat. This appears to be omental in character. In the lower end of the ovary is what appears to be a collapsed corpus luteum cyst. It is about 4 cm in length.

Left Side The tube is 11 cm long. At the cornu, it is 1.3 cm in diameter. In its middle portion, it is a little smaller, but in its distal 5 cm it varies from 2 to 2.5 cm in diameter. Where dilated it has thin walls, a brownish inner surface and apparently contains old blood. Its fimbriated end is closed and between the closed end and the ovary, omental fat has become densely adherent. The ovary is 6 cm long and varies from 2 to 3 cm in thickness. It is covered by adhesions.

Histologic Examination—It is difficult to get the exact relationship on account of the ragged condition of the specimen, but on microscopic examination of the left ovarian cyst, which was lined with a brownish membrane, it is seen that the cyst has an inner lining of cylindric epithelium which here and there tends to form folds. At some points beneath the epithelium there is a definite stroma and embedded in this are a few glands (Fig 36). The cyst is partially filled with blood.

In a case (Gyn-Path No 25003) in which the uterus was 13 by 11 cm, the enlargement was due to a submucous myoma. On the posterior surface of the cervix and lower part of the body of the uterus was the most widespread adenomyoma of the rectovaginal septum that I have even seen (Fig 16). I had literally to cut the cervix away from the rectum.

On the surface of, and intimately attached to, the right ovary was a miniature uterine cavity (Fig 21). The glands in this showed a moderate hypertrophy. Other sections from the same ovary showed a diffuse adenomyoma intimately blended with the ovarian tissue, so intimately that no line of demarcation could be detected. It must be remembered, however, that this ovary was firmly glued to and continuous with the diffuse adenomyoma that occupied the posterior surface of the uterus. It is quite possible that the uterine mucosa on the surface of this ovary was due to an overflow of the adenomyoma of the rectovaginal septum.

On Oct 25, 1919, I received a very interesting letter from Dr Otto Schwarz of St Louis. In it he referred at length to several cases of adenomyoma that he had recently seen. Among other specimens examined was one in which the ovary contained uterine mucosa. Dr Schwarz said

The ovarian case was most interesting, this ovary was removed about a year and a half ago. It was about the size of a hen's egg and showed nothing unusual externally. On section it showed several cavities which were filled with blood, partly clotted. Two large blocks were cut transversely across



Fig 36 (Case 13) —A small ovarian cyst lined in part by uterine mucosa. The debris in the upper part of the picture is composed chiefly of old blood. The cyst wall is lined by one layer of cylindric epithelium. In places, this lies in direct contact with the ovarian tissue but here and there is separated by a definite stroma. Near the right the stroma is very evident and embedded in it is a gland resembling those of the body of the uterus. For the gross appearance, see Figure 35.

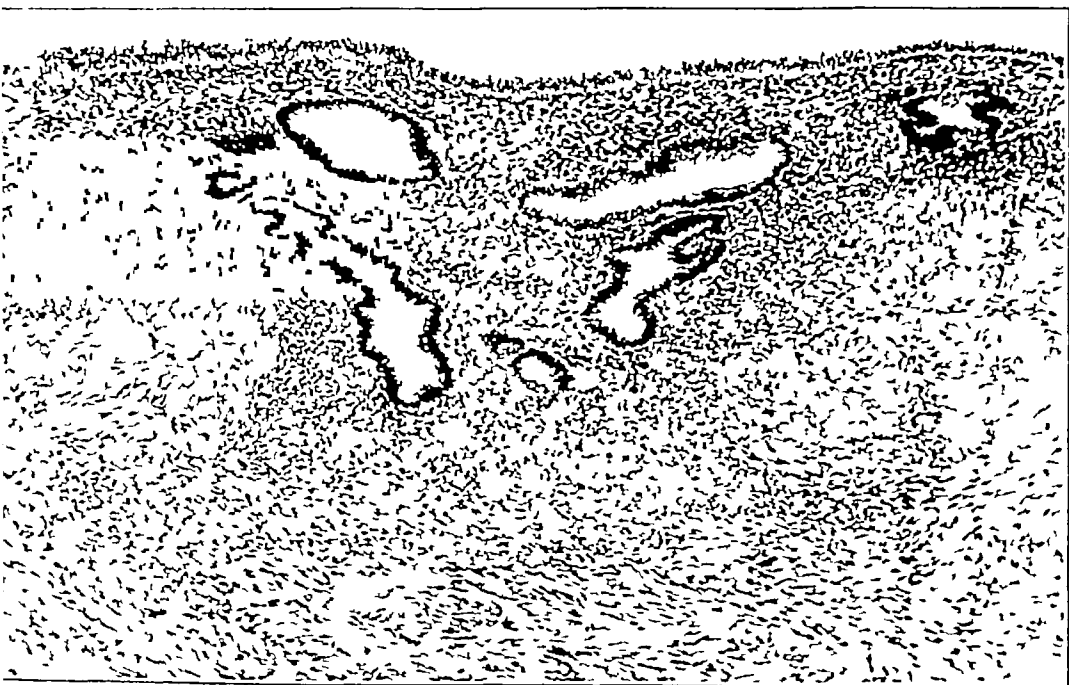


Fig 37 —Uterine mucosa lining a small cyst in the ovary. The specimen was sent me by Dr. Otto Schwarz of St. Louis, Mo. The cyst wall is lined with cylindric epithelium. Beneath this in the central portion of the picture is a definite mucosa containing stroma and glands similar to those found in the body of the uterus.

the ovary In one of the sections I enclose the mucosa appears to communicate with the surface but this is due to a tear Throughout the entire two blocks, the abnormal structure was well within the ovary The sections show the lesion well demarcated from the rest of the stroma of the ovary There are two cavities These are lined with tissue similar to the endometrium

I had the opportunity of examining other sections of the ovary with Dr Schwarz in his laboratory at the Washington University in St Louis a few months later It is a beautiful example of an ovary containing miniature uterine cavities Figure 37 is a photomicrograph that I have had made from one of Dr Schwarz' sections



Fig 38 (Case 14)—Cyst of the right uterosacral ligament During an operation for general pelvic adhesions the cyst noted in the right uterosacral ligament was found It was rather spherical 1.5 cm in diameter, and was filled with brownish putty like material It at once reminded me of an adenomyoma Histologic examination, however, failed to reveal glands or any epithelial lining to the cyst

From the foregoing it is evident that in due time a sufficient number of cases will undoubtedly be reported, and then we shall possibly be able to give a composite picture of both the clinical course and of the histologic changes that occur in this most unusual group of cases

ADENOMYOMA OF THE UTERO-OVARIAN LIGAMENT

These are naturally of little clinical significance and will be recognized only in the laboratory I have reported one case A multinodular myomatous uterus was removed, and springing from the

utero-ovarian ligament was a myoma several centimeters in diameter. In the center of this were islands of typical uterine mucosa.

(This case was reported at length in my book on Adenomyoma of the Uterus, page 140, Figs 41 and 42.)

ADENOMYOMA OF THE UTEROSACRAL LIGAMENT

Several years ago my colleague, Dr William Wood Russell, removed a pea-sized nodule from the right uterosacral ligament. On histologic examination it presented a typical adenomyomatous picture.

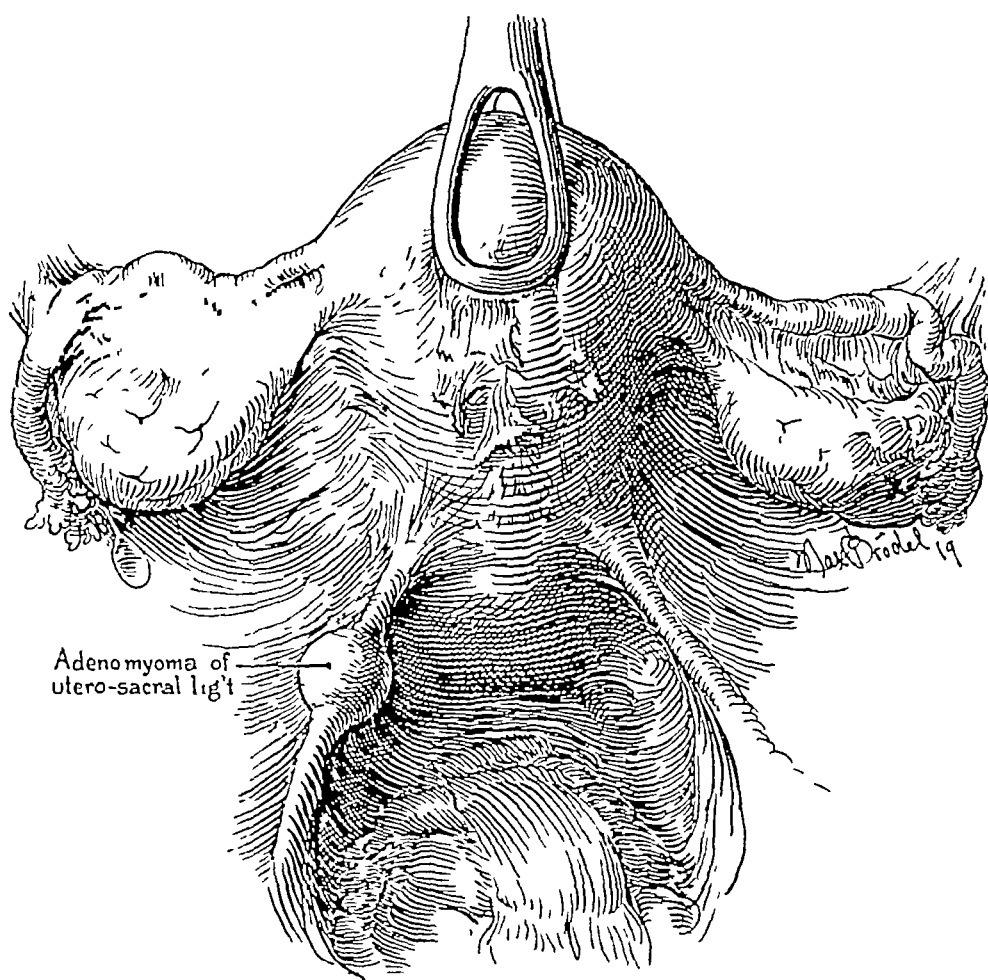


Fig. 39 (Case 15) — Adenomyoma of the left uterosacral ligament. On the posterior surface of the uterus are numerous adhesions. Both ovaries were lightly adherent. It was possible to save all the pelvic structures. In the left uterosacral ligament is a well circumscribed spherical nodule. This had a slightly yellowish brown tinge. For the histologic picture see Figure 40. It was a typical adenomyoma.

Since then I have seen a cyst 1.5 cm. in diameter apparently springing from the right uterosacral ligament. It contained yellowish-brown putty-like material. It may belong to this group but of this I cannot speak with certainty as the histologic picture was not very definite.

CASE 14—Possible adenomyoma of the right uterosacral ligament (Fig 38)

History (Gyn No 23906)—A B, aged 28, colored, was admitted to the Johns Hopkins Hospital on April 5, 1918. In the course of an operation for intestinal and omental adhesions and bilateral ovarian cyst, a small nodule was found in the right uterosacral ligament



Fig 40 (Case 15)—Adenomyoma of the left uterosacral ligament. For the gross appearance of the nodule see Figure 39. Some of the glands lie in direct contact with the muscle, others are surrounded by the characteristic stroma.

Operation and Result—The midline scar of a previous operation was excised. The omentum was found adherent along the line of the old scar. Scattered over the omentum and over the pelvic peritoneum were several small nodules varying from 2 to 3 mm in diameter. These were made up of a brownish, putty-like material.

The body of the uterus was firmly attached to the abdominal wall to which it had evidently been sutured at a former operation. It was freed. There was a cyst about 5 cm. in diameter on the left side, this was resected. On the right side was a small cyst. This was also resected.

A tumor about 15 cm. in diameter was seen in the right uterosacral ligament, 3 cm. from the cervix (Fig. 38). This tumor felt rather firm and was covered with peritoneum. I dissected the right ureter free and pushed it outward. The peritoneum over the tumor was then opened, and the tumor

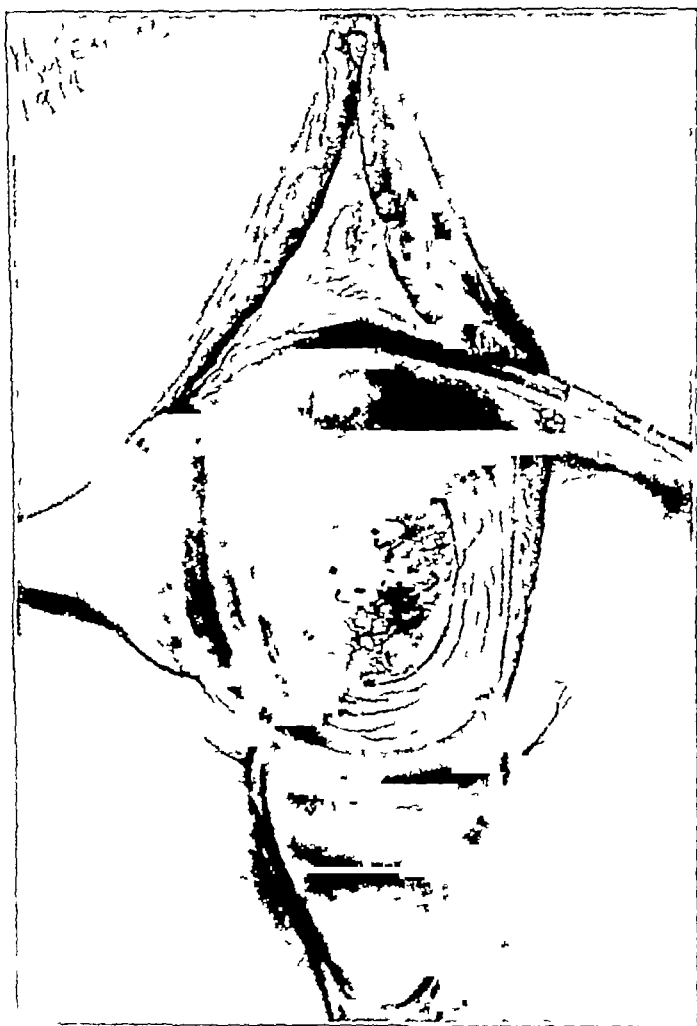


FIG. 41 (Case 16).—Adenomyoma of the rectovaginal septum. The neck of the uterus has been drawn strongly forward. Just posterior to the cervix is an oval and slightly raised area about 2.5 by 2 cm. The surface of this is roughened and lobulated. The surfaces of some of the lobulations are somewhat cystic and a few of them were bluish black, indicating that they contained old menstrual blood. This area was firmly fixed to the right side of the pelvis. For the abdominal picture see Figure 42 and for the histologic picture Figure 43.

found to be yellowish red. It was excised. During its removal there was an escape of a light yellow oily caseous material. The peritoneum was brought together and the abdomen closed. A small cigaret drain was laid in the lower angle of the abdominal incision. The patient was discharged April 29, 1919.

Examination of Specimen (Gyn Path No 23986)—The specimen consists of a collapsed cyst, 1.5 cm in diameter. This, as noted at operation, apparently sprang from the right uterosacral ligament. It contained yellowish brown, putty-like material which escaped during the operation.

Histologic Examination—This revealed a wall consisting in large measure of fibrous tissue. There was no trace of epithelium.

Clinically, this case bore a striking resemblance to an adenomyoma, but whether it was actually an adenomyoma that had undergone retrograde changes, it is, of course, impossible to determine. We can think of nothing else that would occasion such a condition.

On May 20, 1919, I operated on a patient who had numerous pelvic adhesions. In the left uterosacral ligament a short distance from the uterus was a rounded nodule 1.5 cm in diameter. I isolated the left ureter and then removed the nodule, bringing the several ends of the ligament together again. This nodule on histologic examination proved to be a typical adenomyoma. The case is as follows.

CASE 15—*Adenomyoma of the uterosacral ligament* (Figs 39 and 40)

History—Miss N. E. T., aged 36, white, was admitted to the Church Home and Infirmary (No 21398) on May 19, 1919. I saw her in consultation with Dr. A. E. Plumb on April 24. Her menses began at 15. At first, they were regular, but for a year they had at times been a week ahead. On the second day they were accompanied by a good deal of pain. The last period had begun two weeks before I saw her.

Two years ago, she had an attack of acute appendicitis and for six months had had intense pain above the pubic bone. On examination, I found that she had a good deal of discomfort just above the symphysis and some tenderness in the appendix region. The outlet was slightly relaxed, the cervix was forward, the body of the uterus back on the bowel. No thickening could be made out on either side.

Operation and Result—May 20, 1919, we dilated thoroughly. On opening the abdomen, we found the body of the uterus adherent to the rectum. Both tubes and ovaries were also adherent. The adhesions were loosened and the fimbriated ends of both tubes were found to be normal.

In the left uterosacral ligament was a thickening, 1.5 cm in diameter (Fig 39). This had a slightly yellowish brown tinge. It strongly suggested an adenomyoma, but I could not say with any degree of definiteness because the ovary was adherent over it. The ovary, however, did not contain any corpus luteum. After releasing the adhesions, we dissected out the left ureter so that we would know exactly where we were. We then cut away the growth from the left uterosacral ligament and in so doing cut across the uterine artery which was immediately grasped and tied. After cutting away the growth in the uterosacral ligament, we brought the ends of the ligament together with catgut, made a purse-string suture over the area and drew things together leaving the site of the nodule perfectly smooth. We then attached the fundus to the anterior abdominal wall with one plain and two chromicized catgut sutures just to hold the uterus up in position for a month or two and give it a chance to diminish in size. We feared there might be a low grade infection and consequently did not attempt to shorten the round

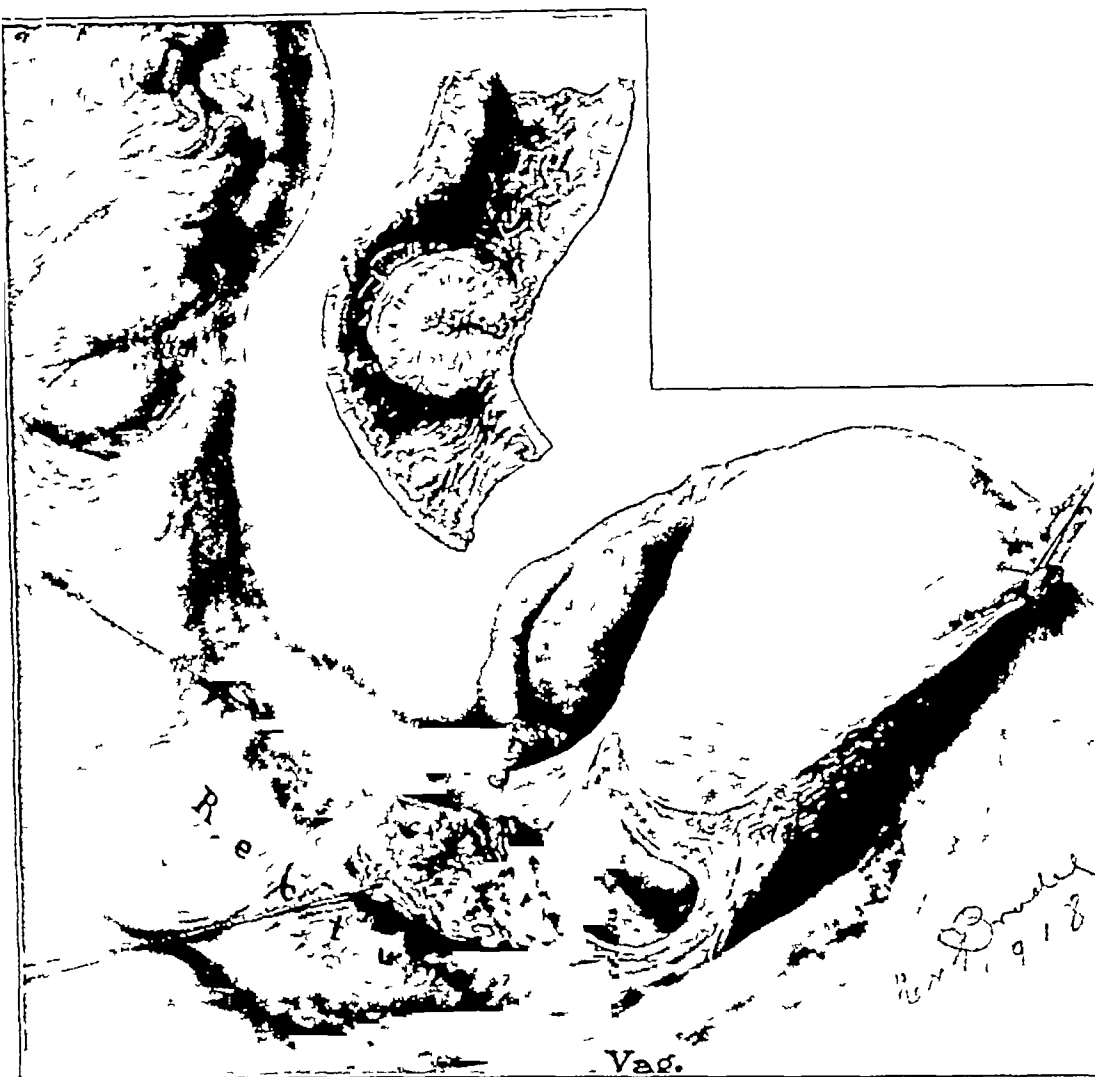


Fig. 42 (Case 16)—Adenomyoma of the rectovaginal septum, independent adenomyoma of the sigmoid almost completely blocking the lumen of the bowel. The right appendages have been removed, the right broad ligament opened up, the right uterine artery ligated and cut and the ureter dissected out. The vagina has been opened and the adenomyomatous thickening on the posterior vaginal wall cut away from the vagina and left attached to the rectum. We were preparing to push the adenomyomatous area together with the adjacent rectum down so that it would be entirely extraperitoneal and so that it could be removed through the vagina a few days later. At this moment, however, we noted the puckered area at the pelvic brim. This bore a strong resemblance to carcinoma but no metastases could be found so we came to the conclusion that it also might be an adenomyoma. The peritoneum of the sigmoid was then severed on either side to a point well above this second growth, the entire mass was pushed down to the pelvic floor and the peritoneum so drawn over it that the entire area was practically extraperitoneal. The abdomen was then drained. We expected to remove the entire diseased area from below at a later date. The patient, however, died of infection. At necropsy the sigmoid growth was found as indicated by the picture to have blocked almost completely the lumen of the bowel. It was a typical adenomyoma. This accounted for the fact that the bowel symptoms were so marked at the time of menstrual period. For the histologic picture of the adenomyoma of the sigmoid see Figure 43.

ligaments We removed the appendix which was small, but the meso-appendix showed scars of old trouble The patient was discharged June 12, 1919

September 22, the patient looked very much better The uterus was in perfect position and there was no thickening anywhere in the pelvis

Examination of Specimen (Gyn Path No 25042)—It was noted at the time of operation that this nodule was 1.5 cm in diameter On section it is found to be composed of nonstriped muscle and fibrous tissue, and embedded in this are one or more minute discrete myomas This nodule also contains a small amount of adipose tissue The myomatous and fibrous tissue tends to spread out into the surrounding fat Scattered throughout the diffuse myoma are numerous glands (Fig 40) lined with one layer of cylindric epithelium A few of the glands occur singly and lie in direct contact with the muscle They tend, however, to occur in groups and are surrounded by the characteristic stroma Some of the dilated glands contain fresh blood, others debris and exfoliated epithelial cells which have swollen, become spherical and contain yellowish brown pigment—the remnant of old menstrual blood

This is a well defined example of adenomyoma of the uterosacral ligament

ADENOMYOMA OF THE SIGMOID FLEXURE

In February, 1918, Dr Thomas E Neill of Washington, D C, referred to me a patient, aged 26, complaining of most excruciating menstrual periods Since April, 1917, she had had diarrhea and with the beginning of each period she would have definite intestinal spasms three or four times a day These would last two days and they would occur just at the time the patient went to stool In September, she was put on a milk and egg diet Her digestion was very much upset and she became constipated During the last three or four periods she had had pain in the lower bowel commencing about twenty-four hours before the period She also had some bleeding from the bowel and had spasmodic contraction of the lower bowel causing nausea and retching

On vaginal examination, I found a hard, slightly nodular and raised area in the vaginal vault directly behind the cervix It was evident that this tumor contained several small cysts

At operation we found, in addition to the adenomyoma of the rectovaginal septum, an independent growth in the sigmoid near the pelvic brim This presented the typical appearance of carcinoma and I at once carried my hand up to the liver to see if there were any metastases None being felt, I thought there might possibly be some relationship between the adenomyoma of the septum and that near the pelvic brim As the patient's condition was not very good, we just loosened up the sigmoid and drew it down extraperitoneally hoping to remove it at a second operation a few days later Unfortunately, the patient developed a streptococcus peritonitis and died At necropsy, it was found that the sigmoid growth was a typical adenomyoma and that there was not the slightest trace of cancer

This case is of such interest that I shall report it in detail



FIG. 51 (Case 16) — Adenomyoma of the uterine neck totally independent of a coexisting adenomyoma of the rectovaginal septum. This is a photomicrograph of a section taken from the normal growth seen in Figure 42. The rectal mucosa *a* is perfectly normal. At *b* the underlying muscular walls are greatly thickened. Scattered throughout the muscular tissue were uterine glands surrounded by the characteristic stroma. The tissue was a cellular brittle and it was impossible to obtain thin sections. Nevertheless, at *c* we can see more marked adenomyoma in the muscle.

CASE 16 (Septum Case 19) —*Adenomyoma of the rectovaginal septum with an independent adenomyoma in the sigmoid flexure near the pelvic brim, clinically closely simulating a carcinoma of the sigmoid and markedly narrowing the lumen of the bowel* (Figs 41, 42 and 43)

History (Gyn No 23764, Gyn Path No 23891) —Mrs G S, aged 26, was referred to me by Dr Thomas E Neill of Washington on Feb 11, 1918. Her menses began at 13. When 14, they occurred every three weeks. She was dilated and curetted when 16, and was gradually having more comfortable periods. The flow now lasted three and four days, formerly it lasted from ten days to two weeks. She had had severe headaches, but these had been

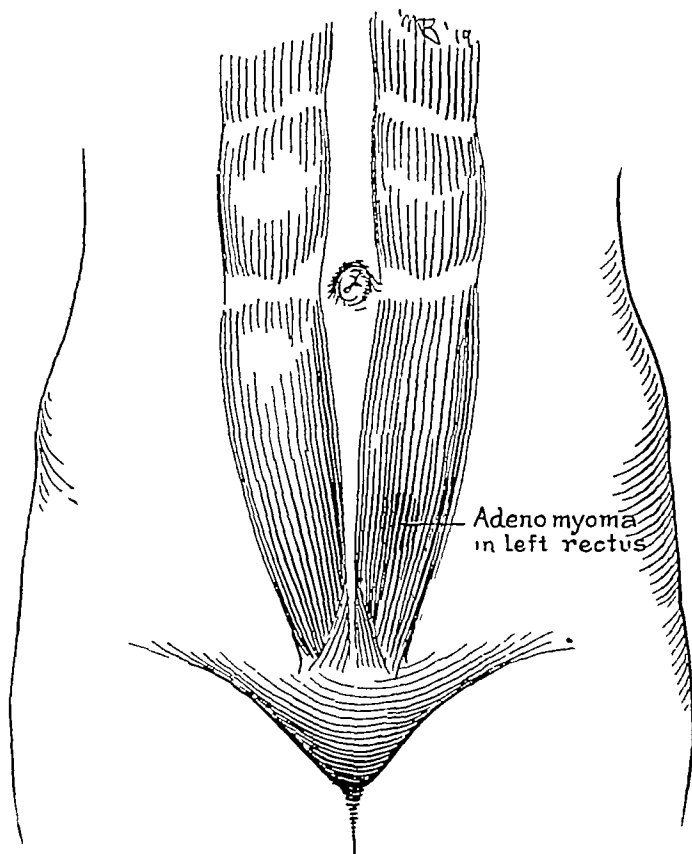


Fig 44 —Adenomyoma in the left rectus muscle. Dr Shallenberger's case. For the histologic picture, see Figures 45 and 46.

diminishing. She had also had the marked intestinal symptoms referred to above. Her last period was two weeks before I saw her. She gave no history of any previous serious illness.

Examination —On pelvic examination, the outlet was found to be slightly relaxed, the cervix pointed forward. Just behind the cervix was a globular, somewhat lobulated mass, 2 cm across, 2 cm from above downward. It commenced directly behind the cervix. The body of the uterus itself was normal in size, in good position, and no thickening could be made out on either side.

On admission to the Johns Hopkins Hospital, the patient had hemoglobin of 78 per cent. She was in rather poor condition and I put her on forced

nourishment for two weeks before attempting any abdominal procedure. Dr M. Bloomfield examined the lungs and found evidence of old tuberculosis in the left apex.

Operation and Result—April 4, 1918, we operated. First of all we grasped the posterior lip of the cervix and drew it forward, put a retractor in posteriorly and then one on the right. We were then enabled to see an oval area about 2.5 by 2 cm, directly behind the cervix (Fig. 41). This was slightly nodular and in the center of some of the nodules was a shiny condition indicating that at such points a small cyst existed. One or two of these were bluish black in color, and there was absolutely no doubt that we were deal-



Fig. 45—Adenomyoma in the left rectus muscle. For the location of the tumor see Figure 44. The nodule consisted of nonstriated muscle and fibrous tissue and scattered throughout it were areas of typical uterine mucosa.

ing with an adenomyoma of the rectovaginal septum. The edge of the growth was slightly raised, probably 1 mm from the surface of the vaginal mucosa. We made an incision posterior to the cervix, separated the cervix from the vagina and then on the right side we cut the vaginal mucosa near the growth and loosened it up as much as possible. We then packed the vagina tightly with gauze and made a median abdominal incision. The right tube and ovary were removed in order that we might get into the right broad ligament satisfactorily. We dissected out the right ureter, cut the right uterine artery and

then separated the bladder peritoneum from the anterior surface of the uterus to a point slightly beyond the median line. We gradually loosened up the growth in the right broad ligament from the peritoneum on the right side of the rectum for a short distance and then cut the vaginal mucosa around it so that we finally had the uterus shoved over to the left side and a button of the vaginal mucosa containing the growth still left attached to the rectum (Fig 42). We had partly closed the vagina, after pulling the rectal growth down into it, when we noticed a constriction about six inches above where the rectal growth had been. Whether the growth in the upper part of the sigmoid was carcinoma or not it was impossible to tell. After examining the pelvic glands and also the liver and finding no evidence of metastases nor any enlarged lymph glands, I came to the conclusion that this might be another adenomyoma, although I had never seen one in such a position. We cut the peritoneum on either side of the sigmoid up as high as the pelvic brim,



Fig 46—Adenomyoma in the left rectus muscle. For the location of the tumor, see Figure 44. Scattered throughout the myoma are areas of normal uterine mucosa.

loosened up the rectum as far as possible without interfering with its blood supply and then pushed the sigmoid well down into the pelvis and drew the pelvic peritoneum over to the pelvic brim so we could wall off this area of the sigmoid. When we had finished the operation, the sigmoid had been pushed down extraperitoneally. A drain was left in the lower angle of the incision down behind the uterus. The patient was in fair condition.

We hoped at a later date to draw the bowel out through the vagina and perform an end to end anastomosis if possible. To have done anything more at the time would undoubtedly have caused the death of the patient.

For the first twenty-four hours the patient did fairly well, but the next day she commenced to vomit a small amount of greenish fluid. There was a good deal of abdominal distention.

On March 7, the patient was delirious, vomited frequently, and was very restless, tossing from side to side. On March 8, at 3 30 p m, I performed an enterostomy, thinking there might be intestinal obstruction. The bowel was relatively smooth, but there was some infection low down in the pelvis. The patient died at 9 p m.

Necropsy Findings—A definite peritonitis existed. The rectovaginal growth consisted of typical adenomyomatous tissue, and the tumor that projected in the sigmoid near the pelvic brim and markedly constricted the lumen of the bowel also consisted of characteristic adenomyomatous tissue (Fig 43).

Cuthbert Lockyer,⁵ in his excellent book on "Fibroids and Allied Tumors," gives us the best resume of the literature on adenomyoma. In it, he refers at length to an interesting case reported by Robert Meyer⁶. On referring to Meyer's article I found that the patient was 45 years of age, and that Professor Mackenrodt had performed a resection in 1907 as the patient had signs of stenosis of the bowel.

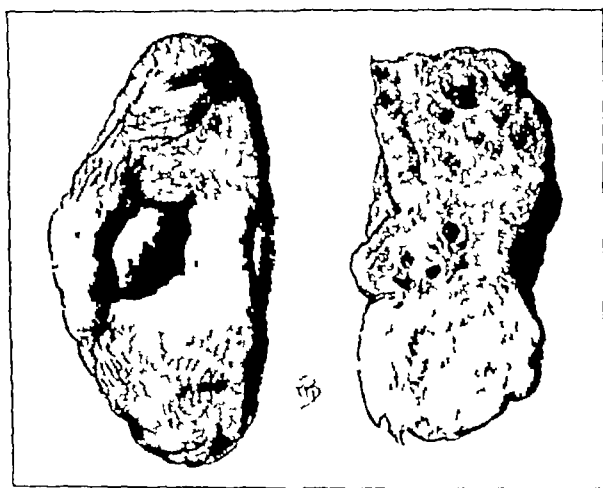


Fig 47 (Case 17)—Adenomyoma of the umbilicus. Dr Guthrie's case. Projecting from the umbilical depression is a small tumor. This was 1.5 cm long. On section it was seen to contain several small cysts. Some of them were yellowish brown color. For the low power picture see Figure 48. For the higher magnification Figure 49.

The specimen consisted of a segment of the bowel 8 cm in length. The bowel lumen over an area 1.5 cm long was markedly narrowed, there being just a slitlike opening. The mesocolon at this point and also the overlying bowel mucosa were markedly thickened. In the mesocolon between the layer of fat and the muscular wall of the

5 Lockyer, Cuthbert. *Fibroids and Allied Tumors*, New York: the Macmillan Company, 1917.

6 Meyer, Robert. Ueber entzündliche heterotope Epithelwucherungen im weiblichen Genitalgebiete und über eine bis in die Wurzel des Mesocolon ausgedehnte benigne Wucherung des Darmepithels, *Virchows Arch f path Anat* 195: 487, 1919.

sigmoid was an irregular fanlike connective-tissue tumor, diffuse in character, and strongly suggesting an adenomyoma. The tumor projected into the bowel and produced a folding of the overlying mucous membrane.

On histologic examination, the mucous membrane of the bowel over the tumor folds was found to have practically disappeared, the surface consisting of granulation tissue. The tumor consisted of adenomyomatous tissue.

Meyer's pictures leave no doubt that he was dealing with an adenomyoma of the sigmoid, an adenomyoma of a type resembling in nearly every particular that found in the uterus. This is the first case of this character that I have found any record of. It was clearly described in Cuthbert Lockyer's recent publication.

On Oct. 24, 1919, I received a most interesting letter from my friend, Dr. G. Brown Miller of Washington, D. C., the contents of which have a definite bearing on the association of adenomyoma of the rectovaginal septum with secondary adenomyoma in the sigmoid.

Mrs. P., aged 36, with no children, came to see Dr. Miller on June 26, 1919, complaining of profuse, prolonged and painful menstruation, pain in the pelvis and pain on defecation. She had recently lost a good deal of weight but was still well nourished although somewhat anemic.

Vaginal examination showed the cervix to be large and hard, and a small polypoid tumor was protruding from the os. In the upper part of the posterior vaginal vault was an irregular, hard, nodular tumor mass the size of a walnut. It was intimately connected with the cervix, rectum and broad ligament. The rectal mucosa over the tumor was intact but was intimately adherent to the mass. The uterus was retroverted and moderately enlarged. A diagnosis of adenomyoma of the rectovaginal septum was made.

The patient was sent to the Columbia Hospital and was operated on a few days later. I was assisted by Dr. Neill. When more carefully examined immediately before operation the nodules in the vaginal vault were seen to contain small bluish cysts the size of a pin.

On opening the abdomen the first thing which attracted one's attention was a mass the size of a large lemon which was situated in the upper part of the rectum or lower sigmoid. This seemed to encircle the lumen of the bowel. The patient gave no history of hemorrhage from the bowel or of bloody stools. A total hysterectomy was performed. It was a difficult operation on account of the fixation of the uterus. In attempting to separate the growth from the rectum, an opening was made in the bowel after which the whole involvement of the rectum by the tumor was cut away and the rectum was sutured.

No attempt was made to resect the growth in the sigmoid. The patient left the table in bad condition. Her pulse was rapid and she was much shocked. She improved and the next day was much better. I left town the following day and was hopeful that she might recover, but learned from Dr. Neill that about eight or nine days after the operation she apparently developed peritonitis and soon died.

Mahle and MacCarty⁷ report a very interesting case of adenomyoma of the sigmoid observed in the Mayo Clinic

CASE 4—The adenomyoma of the sigmoid occurred in a patient, aged 31, who had been married eleven years and pregnant once. She had had an appendectomy, salpingectomy, and partial oophorectomy performed elsewhere. At that time she was told that she had a tumor of the lower bowel which would



Fig 48 (Case 17)—Adenomyoma of the umbilicus. This is a low power picture of the umbilical tumor seen in Figure 47. The surface is covered with normal skin. Scattered everywhere throughout the tumor are glands, many of them cystic and not a few surrounded by a definite stroma that stains rather deeply. For the higher power, see Figure 49.

become a cancer. She presented herself at the clinic because of this tumor. Roentgen ray of the colon, and a proctosigmoidoscopic examination proved negative.

⁷ Mahle, A. E., and MacCarty, W. C. Ectopic Adenomyoma of Uterine Type (A Report of Ten Cases), *J. Lab. & Clin. Med.* 5:221 (Jan.) 1920.

At operation a tumor mass was found encircling the sigmoid, involving a segment of the bowel 4 cm in length. The sigmoid and the bladder were adherent to a mass around the uterus. Twelve centimeters of sigmoid were removed as well as "tarry" cysts of both ovaries.

Histologic examination of the sigmoid growth showed the characteristic picture of adenomyoma. Mahle and MacCarty refer to an adenomyoma of the sigmoid observed by Leitch.

Further studies will undoubtedly bring to light other cases and it is highly probable that some cases heretofore considered to have been cancer were as a matter of fact adenomyomas.

ADENOMYOMA OF THE RECTUS MUSCLE

These growths are exceedingly rare. Dr. William F. Shallenberger of Atlanta kindly sent me a resumé of the history of his case on Nov 8, 1919.

History—Mrs. C. E. D., aged 34, had been married more than ten years. Nine and a half years ago she had an abortion. Curettage was performed for retained membranes and the dilator passed through the retroflexed uterus at the cervical uterine junction. The body of the uterus was torn half loose from the cervix before the accident was discovered. The patient evidenced considerable shock, was rushed to the hospital, the abdomen was opened and the damage repaired.

Dr. Shallenberger also learned that the patient had a second pregnancy eight years ago. She went to term, had a normal labor but following labor a hematoma developed in the left broad ligament and vaginal wall. This had to be opened through the vagina. The patient's health has been very good since the last labor, aside from a slight attack of cystitis three years ago and a streptococcus infection of the foot six months ago.

The menstrual history was normal in every way.

Present Illness—Three days ago the patient noticed a little soreness in the lower abdomen just to the left of the lower angle of the abdominal scar (Fig. 44). On feeling this area she noticed a small tender swelling. She thought that a hernia was developing.

On inspection there was a slight fulness just to the left of the midline and slightly above the symphysis. On palpitation a small firm nodule could be felt apparently in the belly of the rectus muscle. This did not seem to be associated with the scar of the incision and there was no impulse on coughing or straining, and the nodule did not increase in size when the patient stood. Dr. Shallenberger thought he was dealing with a hernia or with a dermoid tumor of the rectus muscle.

Treatment—The patient was put to bed and an ice cap was placed over the lower abdomen. The pain and soreness were not relieved and the nodule apparently increased somewhat in size during the next four days. Dr. Shallenberger then decided to remove the nodule. The entire lower end of the left rectus was removed. The tumor was about 2.5 to 3 cm in length, about 1.5 cm in breadth and 1.5 cm thick. It had no definite capsule.

On cutting into the tumor Dr Shallenberger found that it presented a dark grayish mottled appearance and that it was firm and fibrous in character

The operation was performed eleven months ago and the patient made an uneventful recovery

Sections from this growth sent to me by Dr Shallenberger consist of nonstriped muscle. Scattered throughout this are areas of characteristic uterine stroma containing normal appearing uterine glands (Figs 45 and 46). The cavities of some of the glands contain blood and in the stroma at some points is brown pigment

The tumor in the case reported by Dr Shallenberger is without doubt an adenomyoma occurring in the left rectus muscle. It is the first one of this character that I have ever heard of. From its location it could not for a moment be confused with adenomyoma of the round ligament which, although it presents exactly the same histologic picture, is usually situated at or near the external or the internal ring

Mahle and MacCarty⁷ record two cases of adenomyoma of the abdominal wall

CASE 2—This patient, aged 30, complained of a tender lump, of two years' duration, in the lower abdominal wall, under a previous laparotomy scar. The lump was painful at the time of menstruation

On examination a palpable mass, 3 cm in diameter, was found beneath the lower end of a median laparotomy scar, this was hard, nodular and painful to touch. It was apparently not attached to the uterus, and clinically, was thought to be a fibrous tumor in a previous laparotomy wound

At operation, the mass was removed, it extended through the abdominal muscles, and was attached to the left tube about 4 cm from the uterine horn

CASE 3—This patient, aged 46, had had a ventral suspension performed several years before and had been pregnant nine times, the last pregnancy occurring ten years before. She complained of lumps in the abdominal wall, which she had noticed for the last year. These lumps had not grown noticeably larger but had always been painful following menstruation

On examination, a mass was found in the suprapubic region, apparently in the abdominal wall, movable with it, and possibly connected with the fundus of the uterus. Clinically, it was thought to be a fibrous growth, attached to the abdominal wall on a previously ventrosuspended uterus

At operation, the fundus of the uterus was found attached to the abdominal wall. The tumor, 8 cm in diameter, was situated to the right of the midline, and extended down to the right side of the uterus. It was solid, with glandular, cystic areas filled with black pigment. Because of its extension into the retroperitoneal tissue, and apparent inoperability, only a piece of tissue 6 cm in diameter, was excised for diagnosis

ADENOMYOMA OF THE UMBILICUS

From time to time a small thickening has been noted at the umbilicus in women during the child-bearing period. In some of these cases, the tumor has increased in size perceptibly at the menstrual

period, and in a few there has been a discharge of blood from the umbilicus at the period. Occasionally, small bluish black cysts have been noted in the tumor.

Adenomyomas of the umbilicus are always small. On histologic examination, they are found covered over with normal skin. They consist of fibrous tissue and nonstriated muscle, and scattered through-



Fig. 49 (Case 17)—Adenomyoma of the umbilicus. This section is from the umbilical nodule seen in Figure 47. In the center of the field is typical uterine mucosa. Some of the glands are dilated.

out this are islands of typical uterine mucosa. When the history is characteristic, the diagnosis can be made with ease.

It is not necessary for me to discuss this subject in detail, as I have devoted an entire chapter to adenomyomas of this region in my book on the umbilicus.

Removal of the umbilicus is all that is essential in these cases

I shall report briefly on the specimens of two cases of adenomyoma that have recently been sent me for examination

CASE 17—*Adenomyoma of the umbilicus* (Figs 47, 48 and 49)

History—The specimen was sent me by Dr Donald Guthrie of the Robert Packer Hospital, Sayre, Pa, in March, 1919 Dr Guthrie says

"The patient is 46 years of age She has had two children—the youngest 16 years of age Menstruation has been regular The patient has experienced severe pain around the umbilicus at the menstrual period She has noticed this for two years, and at this time discovered an enlargement of the umbilicus She never has had any discharge from it At the menstrual period when the

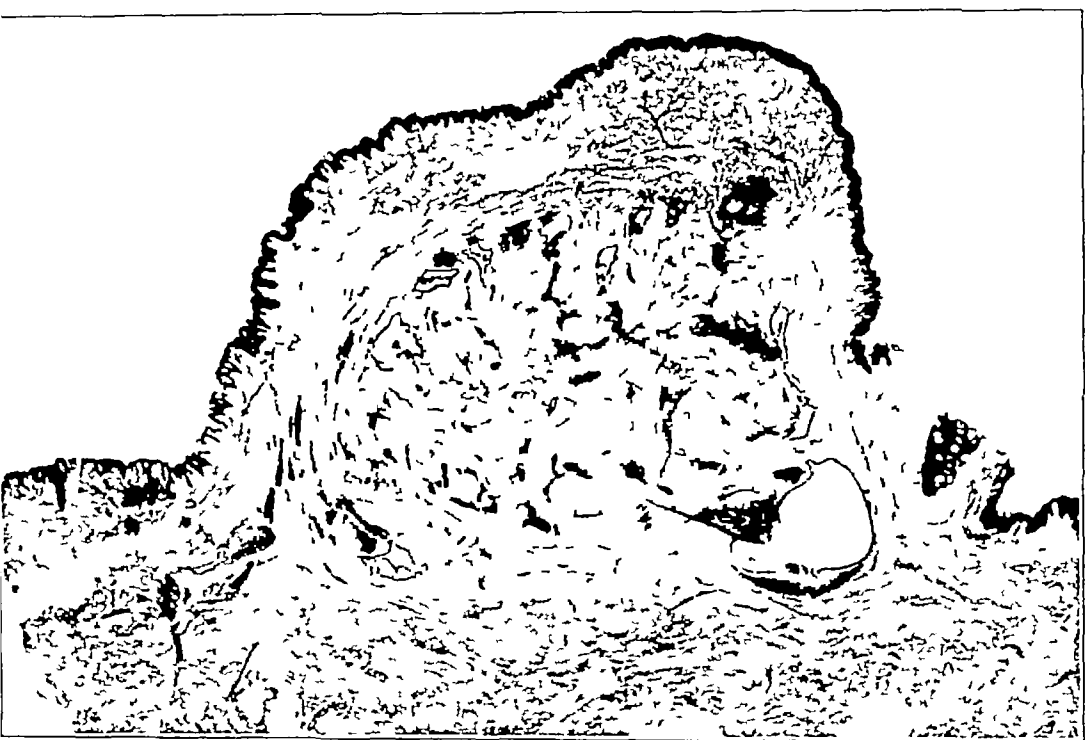


Fig 50 (Case 18)—*Adenomyoma of the umbilicus* The specimen was sent me by Dr Lester Adams The overlying skin is normal The tumor is sharply circumscribed, has a whorled appearance, and has scattered throughout it cystic spaces and dark areas, some of them with glands in their centers For the histologic picture see Figure 51

umbilicus was paining her, the patient experienced some inflammatory symptoms of the bladder She has become very nervous and fearful that she has a cancer"

Dr Guthrie sent me the specimen shortly after its removal

Examination of Specimen (Gyn Path No 24792)—The specimen consists of the umbilicus and of the adjoining skin The umbilical depression is filled with a small growth 1.5 cm in diameter (Fig 47) This on section appears firm, but scattered throughout it are a few cystic spaces, some of them yellowish brown—cancer was suspected clinically



Fig 51 (Case 18)—Adenomyoma of the umbilicus. The overlying skin is normal. Some of the glands are partially surrounded by a definite stroma, others lie in contact with the myomatous tissue. For the low power picture see Figure 50.

Histologic Examination—The low-power picture is well shown in Figure 48. The free surface is covered with normal squamous epithelium. The greater part of the tumor is made up of colonies of glands embedded in a definite stroma. Quite a number of the glands are dilated and filled with grayish or brownish material. Here and there is a perfectly definite miniature uterine cavity.

With a higher power it is seen that the matrix of the tumor is made up of connective tissue with bundles of nonstriated muscle scattered liberally throughout it. Everywhere throughout the tumor are glands. Some are minute and lie in direct contact with the muscle, others are larger and embedded in a rarefied stroma. Many occur in groups and are embedded in a stroma identical with that of the uterine mucosa (Fig 49). This mucosa is in some places so arranged that miniature uterine cavities occur. Some of the gland cavities are filled with blood, and here and there throughout the stroma of the growth are areas of yellowish brown pigment—the remnants of old menstrual blood. One could not wish for a more beautiful example of an adenomyoma of the umbilicus.

CASE 18—*Adenomyoma of the umbilicus* (Figs 50 and 51)

History—This specimen was sent me by Dr. Lester Adams of the Eastern Maine General Hospital, Bangor, Me. M. G., aged 37, was under the care of Dr. Hunt. An umbilical growth was removed on Nov. 8, 1916. About a year before the operation she had noticed pain at the umbilicus at the menstrual period, but at no other time. There was some increase in size of the umbilicus at the periods. Recently the pain and tenderness in the umbilical region had increased markedly.

Examination of Specimen (Gyn. Path. No. 22657)—The specimen consists of a growth, 1.3 cm. in diameter, occupying the umbilical region. On section it is very dense, but at two points are small cysts, the larger being 2 mm. in diameter.

On histologic examination, the overlying skin is found to be normal (Fig 50). The tumor growth is made up of nonstriated muscle and fibrous tissue. Scattered throughout the tumor are large numbers of glands, some occur singly and lie in direct contact with the muscle. The majority, however, occur in groups and are separated from the muscle by a definite stroma (Fig 51). This at some points is rarefied, but in other places is identical with that of the uterine mucosa. In at least one place is a miniature uterine cavity. Some of the glands are filled with blood, others with exfoliated epithelium and debris. In the outlying portions of the tumor are colonies of sweat glands.

This is another example of adenomyoma of the umbilicus.

SUMMARY

From the foregoing, we have seen that adenomyomas, consisting of a matrix of nonstriated muscle and fibrous tissue with typical uterine mucosa scattered throughout, are to be found in the uterus, rectovaginal septum, tubes, round ligaments, utero-ovarian ligaments, uterosacral ligaments, sigmoid flexure, rectus muscle and umbilicus and that we occasionally find large quantities of normal uterine mucosa in the ovary. Adenomyomas form one of the most interesting groups of tumors that we have to deal with in the female pelvis.

STUDIES IN BONE TRANSPLANTATIONS

AN EXPERIMENTAL STUDY OF THE COMPARATIVE SUCCESS OF AUTOGENOUS AND HOMOGENOUS TRANPLANTS OF BONE IN DOGS *

BARNEY BROOKS, M D, AND WILLIAM A HUDSON
ST LOUIS

The extensive clinical and experimental study of the results of transplantation in the same individual of free pieces of bone has led to a clear understanding of the successive steps in the ultimate success or failure of such transplants. The experiments of Phemister,¹ Haas,² Axhausen,³ Thalhimer,⁴ Brooks⁵ and others leave no doubt that the free bone transplant is a source of regeneration of bone and does not act merely as trellis into which bone grows from neighboring sources. These investigators have further shown that the regenerating elements of the bone transplant are the inner layer of the periosteum and the endosteum lining the marrow cavity and the Haversian canals, and that the bone cells in the lacunae take no part in the regeneration of bone. This knowledge places the free autogenous bone transplant on a firm basis as a means of clinical repair of bone defects.

Furthermore, the number of instances in which autogenous free bone transplants have been used in experimental animals gives a fairly definite idea of the proportions of success and failure of such transplants when used to repair defects in the shaft of bone.

In the experimental transplantation of bone in dogs, with the periosteum and marrow surfaces preserved, we have found, barring obvious explanations of failure of the transplant, such as wound infection or poor position of the graft, that such transplants have been successful in all instances in which comparatively young animals have been used. In a series of experiments, reported in a previous paper,⁶ in which old dogs alone were used, it was found that the proportion of successful regenerations of the bone defect by an autogenous bone transplant was reduced to approximately 66 per cent.

The knowledge concerning the transplantation of bone from one individual to another of the same species is very limited. The rather general failure of transplantations of tissue between individuals of

*From the Department of Surgery, Washington University Medical School

1 Phemister Surg, Gynec & Obst **19** 303, 1914

2 Haas Surg, Gynec & Obst **19** 604, 1914

3 Axhausen Arch f klin Chir **88** 23, 1909

4 Thalhimer W M Ann Surg **67** 331 (March) 1918

5 Brooks, Barney Ann Surg **65** 704 (June) 1917

6 Brooks, Barney Ann Surg **69** 113 (Feb) 1919

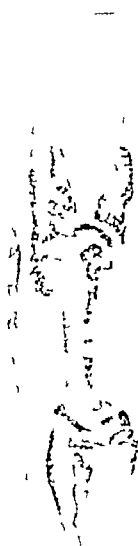
PLATE I



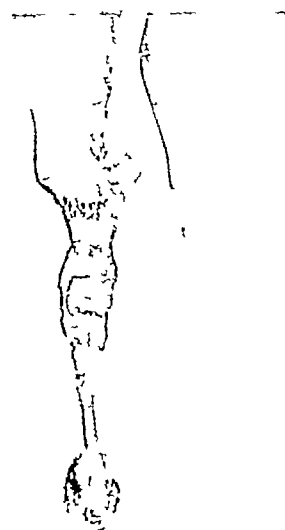
a



b



c



d

Transplants *a* homogenous Experiment 7 A *b* homogenous Experiment 7 B *c* homogenous Experiment 8 A *d* homogenous Experiment 18 A

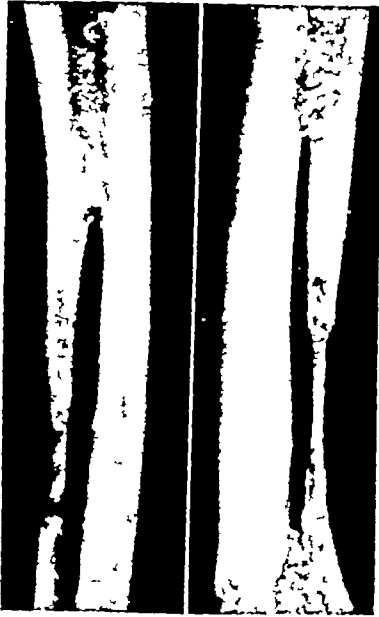
even the same species has led to a fairly general impression that such transplantations are usually ultimately unsuccessful. In experiments in which homogenous transplants of bone have been used, however, successful results have been recorded, although there is no definite knowledge of the proportions of success and failure of homogenous bone transplants.

Ollier⁷ apparently believed that transplantations of periosteum or bone and periosteum were equally successful when used in the individual or in another individual of the same species. He writes that although transplantations of periosteum from an individual of one species to an individual of another species is universally ultimately a failure, no difficulty was encountered in finding regeneration of bone from a transplant of periosteum from a rabbit to another rabbit of a different variety. Ollier's experiments, however, were all done previous to the time of antiseptic surgery, and there were numerous failures, due to wound infection, even in instances in which autogenous transplants were used. Also, Ollier was primarily interested in the proof of the osteogenetic properties of the periosteum, and one gets comparatively little information, other than that bearing directly on this question, from the study of his experiments. It is also of considerable interest to note that Ollier showed that bone was produced from a transplant of periosteum taken from a rabbit which had been dead twenty-five hours and transferred to a living rabbit. He also did experiments to determine the best temperature in which such transplants should be kept until they were used.

Axhausen² reports the results of a number of experiments in which free transplants of bone with periosteum and endosteum were transplanted from one individual to another individual of the same species. The animals used for these experiments were rats, cats and dogs. The transplants were all placed in the soft tissues, and the animals in which the transplants were placed were allowed to live for relatively short periods. The end-results of the transplantations were determined by microscopic study. In these experiments Axhausen found that the homogenous bone transplants regenerated bone. He states that the regeneration of bone is not so noticeable as in instances in which the transplantations were done in the same individual. Axhausen also found that bone grew from transplants removed from animals which had been dead for as long as thirty hours when they were placed in a living individual of the same species.

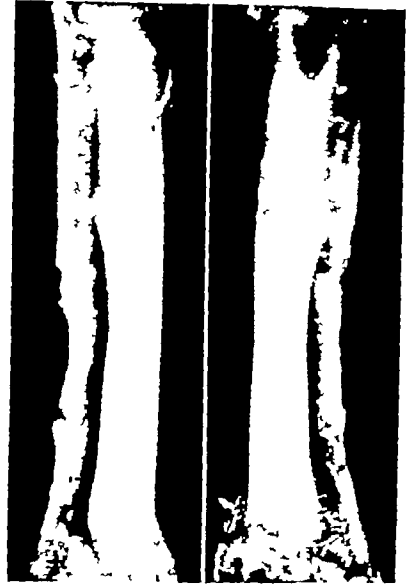
⁷ Ollier. *Traite experimental et clinique de la regeneration des os*, Paris, 1867.

PLATE II



a

b



c

d



e

f



g

h

Transplants *a*, autogenous, *b* homogenous, Experiment 21 A, *c*, autogenous, *d*, homogenous, Experiment 21 B, *e*, autogenous, *f*, homogenous, Experiment 23 A, *g*, autogenous, *h*, homogenous, Experiment 23 B

Lexer⁸ has also reported successful transplantations of bone from one individual to another individual of the same species in his transplantations of entire joints. The success of such extensive transplantations, however, has not been sufficiently convincing to lead to subsequent use of this formidable procedure. Macewen⁹ describes a clinical instance in which a defect in the shaft of the humerus of a child 3 years old was successfully regenerated by transplants of bone from the tibia of another child 6 years old. Lexer reports successful regeneration of bone defect in man from the use of pieces of bone removed from the freshly amputated limbs of other individuals.

From the experiments of Ollier and Acland it would seem, therefore, that transplants of periosteum or bone and periosteum from one individual to another of the same species resulted in some instances in the survival of parts of the transplant and subsequent regeneration of bone. There is no experimental evidence, however, to show the proportion of instances in which this result followed. Furthermore, the mere fact that a transplant survives and regenerates tissue is not conclusive proof of the continued survival of the transplanted tissue. It may happen that a transplant of bone from one individual to another of the same species lives and grows for a time and subsequently atrophies or is completely absorbed. The experiments of Ollier and Acland were not of sufficient duration to test the permanency of the transplant. Also the transplantations were all into soft tissues, and it is known that even transplants of bone into soft parts in the same individual ultimately disappear.

Another problem, which has been suggested in a previous publication,⁶ seemed worth experimental study. It has been shown that autogenous transplants of bone and periosteum result in failure in a considerable proportion of instances if the experimental animals are advanced in age. It was found further that the proportion of successful regenerations of defects in the shafts of bones in old dogs could be increased by a preliminary stimulation of growth in the bone from which the transplant was removed. It would seem possible with a defect in the shaft of a bone in an old dog that such a defect might be bridged by a transplant taken from a young dog with a greater chance of a successful regeneration of the bone defect than if an autogenous graft were used.

The experiments described in this paper were therefore undertaken for the purpose of studying the following problems

⁸ Lexer. *Arch f klin Chir* 86 939, 1908, *ibid* 90 263 1909.

⁹ Macewen. *The Growth of Bone*, Glasgow: James Maclehose and Sons, 1912.

PLATE III



a

b



c

d



e

f



g

h

Transplants *a*, autogenous, *b*, homogenous, Experiment 24 A, *c*, autogenous, *d*, homogenous, Experiment 24 B, *e*, autogenous, *f*, homogenous, Experiment 25 A, *g*, autogenous, *h*, homogenous, Experiment 25 B

1 Is it possible to regenerate, permanently, a defect in the shaft of a bone by bridging this defect with a bone transplant taken from another individual of the same species?

2 In what proportion of instances may a successful result be expected?

3 What is the influence of the ages of the donor and recipient on the proportions of success and failure of homogenous bone transplants?

EXPERIMENTAL METHOD

Dogs were used in all experiments. The operative procedures were carried out with the animals in complete surgical anesthesia. Careful aseptic precautions were taken. In only a few instances did wound infection occur. Those animals which did not die were sacrificed by the administration of chloroform.

The animals were operated on in pairs. An attempt was made to have, as often as available material permitted, each pair an old dog and a young dog. The animals were anesthetized and both forelegs of each animal were prepared for operation. A segment of each ulna from 2.5 to 4 cm. in length with all periosteum was excised. It is to be emphasized that in order for the segment of bone to be removed with all its periosteum, the interosseous membrane between the radius and ulna must be divided with a knife before the resection is begun. A large number of experiments have shown that such a defect will not regenerate without the use of some sort of transplant. One of the defects in each animal was then bridged by an autogenous transplant with its periosteum and endosteum. The other defect in the ulna of each dog was bridged by a homogenous transplant. The homogenous transplants were exchanged between the two animals.

The transplants were in some experiments obtained by cutting a strip of bone from the shaft of the femur with a motor saw. In these instances a strip of bone from 6 to 8 cm. long was cut and subsequently divided. One piece was used as a transplant in the defect in the ulna of the same dog, and the other piece was used to bridge the defect in the ulna of the other animal. In other experiments the transplants were made from the excised segments of the ulnae of the two animals used at each operation. In these cases the segment of the ulna of each animal was split longitudinally, one half was used as an autogenous transplant and the other half as a homogenous transplant. The autogenous transplants were always changed from right to left, or left to right, so that in no case were they simply excised and replaced in the same bed.

This operative procedure gave in each animal two transplants in similar defects in each ulna. One transplant was an autogenous graft and the other a homogenous graft.

PLATE IV



a

b



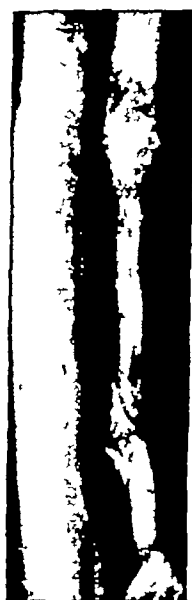
c



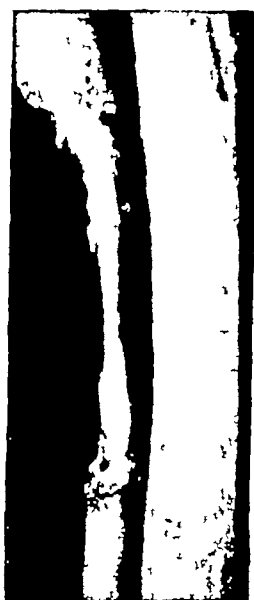
d



e



f



g



h

Transplants *a*, homogenous, *b*, autogenous, Experiment 26 B, *c*, homogenous, Experiment 20 A, *d*, homogenous, Experiment 20 B, *e*, homogenous, Experiment 19 A, *f*, homogenous, Experiment 17 B, *g*, homogenous, Experiment 17 A, *h*, homogenous, Experiment 16 B

After the bone transplants had been snugly placed in the defects in the ulnae the wounds were carefully closed. The skin was always sutured with a cuticular stitch. A dry gauze dressing was applied which usually remained in good condition for twenty-four hours, after which time the operative wounds required no further attention. The animals always began, immediately after recovery from the anesthetic, to use their legs, and the dogs always used their legs apparently with no discomfort.

Beginning in the second week after operation, in some of the experiments, the animals were given twice each week an intraperitoneal injection of 2 c.c. of a saturated aqueous solution of sodium alizarin sulphionate, which has been shown by previous experimental work to be a specific vital stain for growing bone. In the experiments in which it was intended that the animal live for a long period of time, these injections were not given for the reason that frequent injection of this dye frequently results in infection and death of the experimental animal. Also, in the animals which were allowed to live for long periods the vital stain would have added little to the experiment, as in these cases the successful regeneration of the bone defect or the complete failure of the transplantations were the only results to be obtained. In the experiments in which the transplants were studied at the end of shorter periods, it was important to determine the amount and exact location of bone regeneration. For this the vital staining of the growing bone is the ideal method of study, since it makes plainly visible all new bone formed during the period in which the dye was given.

At the expiration of each experiment the bones of the forelegs and one femur were removed and placed in 10 per cent liquor formaldehydi. After the tissues had hardened, the soft tissues were carefully dissected away and the transplants were studied macroscopically and in some experiments microscopically. The femur from each animal was also cleaned of soft parts and the distal half of the femur was split longitudinally.

From the study of the general appearance of the animal and the longitudinal section of the femur, the age of the animal can be estimated approximately. At least from this study an animal may be classified as "young," "adult" or "old." If the dog had the well known characteristics of a "puppy" and the epiphyseal cartilage was still present at the distal end of the femur, the animal was classed as young. If the dog showed gray hairs about the mouth, the teeth markedly worn away, and the bones hard and brittle, with no trace of the junction between the epiphysis and diaphysis at the distal end of the femur, the animal was classified as "old." Dogs which did not show either of these extreme conditions were classified as adult. Great difficulty was

encountered in obtaining "old" dogs. No new-born puppies were used, as the high mortality of very young dogs in laboratory captivity makes it quite impossible to make use of such material without special provisions for the care of such animals.

Experiment 1 A—Young dog Oct 10, 1919

Resection of 25 cm of both ulnae. Defect in right ulna bridged by autogenous transplant removed from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 1 B.

October 22, twelve days. Animal died of peritonitis following injection of alizarin red. Wound in right foreleg healed per primam. Slight discharge from wound in left foreleg. Examination of femur showed animal was a young dog.

Right ulna. Autogenous transplant in good position. Apparently slight infection at one end of transplant. Large amount of bone regeneration on both the periosteal and marrow surfaces.

Left ulna. Homogenous transplant removed from young dog. In good position. Firm fibrous union of ends of transplant and stumps of bones. New bone formation on both periosteal and marrow surfaces of transplant.

Experiment 1 B—Young dog Oct. 10, 1919

Resection of 25 cm of both ulnae. Defect in left ulna bridged by an autogenous transplant from right ulna. Defect in right ulna bridged by a homogenous transplant from ulna of young dog used in Experiment 1 A.

November 10, thirty days. Animal died of peritonitis following injection of alizarin red. Examination of femur showed animal was a young dog. Wounds in foreleg healed per primam.

Left ulna. Autogenous transplant in good position. United to stumps of resected ulna. Large amount of new bone formation from transplant.

Right ulna. Homogenous transplant removed from young dog. Transplant entirely absorbed. No regeneration of bone in defect.

Experiment 2 A—Young dog Oct 18, 1919

Resection of 25 cm of both ulnae. Defect in left ulna bridged by an autogenous transplant from right ulna. Defect in right ulna bridged by a homogenous transplant taken from ulna of dog used in Experiment 2 B.

October 25, seven days. Dog was found dead in cage. Wound in right foreleg healed per primam. Wound in left foreleg discharging. Examination of femur showed animal was a young dog.

Left ulna. Autogenous transplant lay loose in a cavity containing purulent fluid. It was obviously completely necrotic.

Right ulna. Homogenous transplant removed from adult dog. Transplant in fairly good position. Adherent to surrounding soft tissues. Microscopic examination shows areas in transplant in which cells stain normally. The duration of the experiment was too short for regeneration to have become apparent.

Experiment 2 B—Adult dog Oct 18, 1919

Resection of 25 cm of both ulnae. Defect in right ulna bridged by an autogenous transplant. Defect in left ulna bridged by a homogenous transplant taken from young dog of Experiment 2 A.

December 2, forty-five days Animal given alizarin red intraperitoneally
Died of peritonitis Wound in right foreleg healed per primam Wound
in left foreleg discharging Examination of femur showed animal was an
adult dog

Right ulna Autogenous transplant in fairly good position New bone
formation was found along both the periosteal and marrow surfaces of the
transplant More growth on the marrow surface

Left ulna Homogenous transplant had completely disappeared There
was an abscess cavity between the stumps of the resected ulna

Experiment 3 A—Young dog Oct 22, 1919

Resection of 3 cm of both ulnae Defect in right ulna bridged by an
autogenous transplant Defect in left ulna bridged by a homogenous transplant
removed from a young dog used in Experiment 3 B

November 15, twenty-three days Found dead Cause of death not known
Wound in left foreleg healed per primam Small sinus in scar of operation on
right foreleg Animal received two intraperitoneal injections of alizarin red
Examination of bones showed the animal was a young dog

Right ulna Autogenous transplant in good position Slight infection about
one end of transplant There was a large amount of new bone formation
along the entire length of the transplant

Left ulna Homogenous transplant in good position Marked new bone
formation along the entire transplant

Experiment 3 B—Young dog Oct 22, 1919

Resection of 2.5 cm of both ulnae Defect in left ulna bridged by an
autogenous transplant Defect in right ulna bridged by a homogenous trans-
plant taken from ulna of young dog used in Experiment 3 A

November 15, twenty-three days Animal found dead Cause of death
not known Wounds healed per primam Examination of bones showed ani-
mal was a young dog

Left ulna Autogenous transplant in good position New bone forma-
tion along entire length of graft

Right ulna Homogenous transplant in good condition Marked new bone
formation from the entire length of the transplant

Experiment 4 A—Young dog Dec 4, 1919

Resection of 3 cm of both ulnae Defect in left ulna bridged by autog-
enous transplant removed from right ulna Defect in right ulna bridged by
homogenous transplant from dog used in Experiment 4 B

January 2, 1920, twenty-nine days Animal found dead, cause of death
not known Wounds healed per primam Examination of femur showed
animal was a young dog

Left ulna Autogenous transplant in good position United to stumps of
resected ulna by fibrous tissue Parts of transplant viable Small amount of
new bone from transplant

Right ulna Homogenous transplant in good position United by fibrous
tissue to stumps of resected bone Microscopic examination shows parts of
transplants viable with small areas of proliferation of the periosteum with
formation of osteoid tissue.

Experiment 4 B—Adult dog Dec 4, 1919

Resection of 2.5 cm of both ulnae Defect in right ulna bridged by autog-
enous transplant taken from left ulna Defect in left ulna bridged by homog-
enous transplant from dog used in Experiment 4 A

Jan 7, 1920, thirty-four days Animal given vital stain Wounds healed per primam Cause of death not known Examination of femur showed animal was an adult dog

Right ulna Autogenous transplant in good position Firm union between ends of transplant and stumps of ulna There was a large amount of new bone formed on both the periosteal and marrow surfaces of the transplant

Left ulna Homogenous transplant entirely absorbed and replaced by fibrous tissue There was a large amount of new bone formed on the stumps of ulna

Experiment 5 A—Young dog Dec 9, 1919

Resection of 25 cm of both ulnae. Defect in left ulna bridged by autogenous transplant Defect in right ulna bridged by homogenous transplant from dog used in Experiment 5 B

Jan 7, 1920, twenty-nine days Animal received alizarin red intraperitoneally Wounds healed per primam Cause of death not known Examination of femur showed animal was a young dog

Left ulna Autogenous transplant in place and united to stumps of ulna Microscopic examination shows transplant apparently entirely viable Large amount of growth of new bone from transplant

Right ulna Homogenous transplant in place United with stumps of ulna Microscopic examination showed areas of the transplant viable There was one area of definite new bone formation from transplant

Experiment 5 B—Old dog Dec 9, 1919

Animal died of anesthetic during operation Examination of femur showed animal was an old dog

Experiment 6 A—Young dog Oct 28, 1919

Resection of 25 cm of both ulnae Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 6 B

December 3, thirty-six days Animal received injections of alizarin red intraperitoneally Wounds healed per primam Cause of death not known Examination of femur shows animal to be a young dog

Right ulna Autogenous transplant in good position united with stumps of ulna and new bone formed on all surfaces Stumps of ulna show fair growth of new bone

Left ulna Homogenous transplant in place Union with stumps of ulna not firm so that transplant was loosened in cleaning Shows new bone formed on ends of transplant and especially on marrow surface and periosteal surface at distal end

Experiment 6 B—Old dog Oct 28, 1919

Dog died of the anesthetic during operation Examination of the femur showed animal was an old dog

Experiment 7 A—Young dog March 16, 1920

Resection of 25 cm of both ulnae Defect in left ulna bridged by autogenous transplant Defect in right ulna bridged by homogenous transplant from dog used in Experiment 7 B

April 4, nineteen days Animal received injections of alizarin red intraperitoneally Wounds healed per primam Cause of death not known Examination of femur showed animal was a young dog

Left ulna Autogenous transplant in place Very small amount of new bone formation from transplant Stumps of ulna showed a moderate amount of new bone formation

Right ulna Homogenous transplant in good position Firm union with stumps of ulna Marked new bone formation on all surfaces of transplant Moderate amount of new bone formed on stumps of ulna

Experiment 7 B—Young dog March 16, 1920

Resection of 25 cm of both ulnae Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 7 A

April 19, thirty-four days Animal received alizarin red Wounds healed per primam. Sacrificed Examination of femur showed animal was a young dog

Right ulna Autogenous transplant in place, held firmly by tough fibrous tissue About middle of marrow surface was one small island of new bone, otherwise there was no evidence of new bone formation

Left ulna Homogenous transplant in good position and firmly united to stumps of ulna There was a growth of new bone on both periosteal and marrow surfaces

Experiment 8 A—Adult dog March 17, 1920

Resection of 25 cm of both ulnae Defect in right ulna bridged by an autogenous transplant Defect in left ulna bridged by a homogenous transplant from dog used in Experiment 8 B

April 19, thirty-three days Animal received injections alizarin red intraperitoneally Wounds healed per primam Sacrificed and examination of femur showed animal was an adult dog

Right ulna Autogenous transplant in place Union at distal end with stump of ulna by new bone. Proximal end showed little bone formation Over periosteal and marrow surfaces was a fair amount of new bone. Stumps of ulna showed marked new bone formation

Left ulna Homogenous transplant in good position united with stumps of ulna by fibrous tissue On periosteal surface of transplant was a small amount of new bone, while marrow surface showed no new bone formation. Moderate amount of new bone formed on the stumps of the ulna

Experiment 8 B—Adult dog March 17, 1920

Resection of 25 cm of both ulnae Defect in right ulna bridged by autogenous transplant from left ulna Defect in left ulna bridged by homogenous transplant from dog used in Experiment 8 A

April 4, eighteen days Animal died of peritonitis following intraperitoneal injection of alizarin red Both wounds wide open, right discharging pus Examination of femur showed animal was an adult dog

Right ulna Autogenous transplant lost. Stumps of ulna protruding from open wound

Left ulna Homogenous transplant in good position, fair amount of new bone formed on both periosteal and marrow surfaces but no union with stumps of ulna Pus pocket about transplant

Experiment 9 A—Old dog March 19, 1920

Resection of 25 cm. of both ulnae Defect in left ulna bridged by autogenous transplant from the right ulna Defect in right ulna bridged by homogenous transplant from dog used in Experiment 9 B

April 6, eighteen days Animal died of peritonitis following intraperitoneal injection of alizarin red Wounds healed per primam Examination of femur showed animal was an old dog

Left ulna Autogenous transplant in good position Held and covered by fibrous tissue No new bone formation

Right ulna Homogenous transplant in good position Held by fibrous tissue Considerable new bone formed on periosteal and marrow surfaces

Experiment 9 B—Young dog March 19, 1920

Resection of 25 cm of both ulnae Defect in right ulna bridged by autogenous transplant from left ulna Defect in left ulna bridged by homogenous transplant from dog used in Experiment 9 A

April 18, thirty days Animal sacrificed, received alizarin red Wounds healed per primam and examination of femur showed animal was a young dog

Right ulna Autogenous transplant held in good position by fibrous tissue New bone formation on both periosteal and marrow surfaces, especially at the proximal end.

Left ulna Homogenous transplant in good position United firmly with stumps of ulna by fibrous tissue. There was a marked new bone formation on all surfaces, especially on the periosteal surface facing the radius

Experiment 10 A—Young dog March 22, 1920

Resection of 25 cm of both ulnae Defect in left ulna bridged by autogenous transplant from right ulna Defect in right ulna bridged by homogenous transplant from dog used in Experiment 10 B

April 21, thirty days Animal sacrificed, received alizarin red Wounds healed per primam Examination of femur showed animal was a young dog

Left ulna Autogenous transplant position very good Union with stumps of ulna firm and there was a growth of new bone on both periosteal and marrow surfaces of transplant

Right ulna Homogenous transplant slightly overriding proximal stump of ulna, union of a fibrous tissue nature with some new bone formation Union with distal stump firm Both periosteal and marrow surfaces showed a small amount of new bone formation

Experiment 10 B—Adult dog March 22, 1920

Resection of 25 cm of both ulnae Defect in right ulna bridged by autogenous transplant from left ulna Defect in left ulna bridged by homogenous transplant from dog used in Experiment 10 A

April 21, thirty days Animal sacrificed Received injections of alizarin red intraperitoneally Wounds healed per primam Examination of femur showed animal was an adult dog

Right ulna Autogenous transplant in good position Union with distal stump of ulna firm, with proximal stump fibrous Extensive formation of new bone on marrow surface On periosteal surface small amount of new bone

Left ulna Homogenous transplant in good position No new bone formation Transplant apparently was being rapidly absorbed

Experiment 11 A—Young dog March 23, 1920

Resection of 25 cm of both ulnae Defect in left ulna bridged by autogenous transplant from right ulna Defect in right ulna bridged by homogenous transplant from dog used in Experiment 11 B

April 7, fourteen days Animal died of peritonitis following intraperitoneal injection of alizarin red Wounds healed per primam Examination of femur showed animal was a young dog

Left ulna Autogenous transplant in place Along medial edge of defect in ulna was a small portion of the ulna which was about 3 mm in diameter which had been separated from ulna at distal end, but was connected at proximal

end by a bridge of bone about 1 mm in diameter. Along marrow surface of transplant where it was closely related to this segment of bone, there was marked new bone formation.

Right ulna. Homogenous transplant united with both stumps of ulna by fibrous tissue. Small amount of new bone formed on marrow surface.

Experiment 11 B—Adult dog. March 23, 1920.

Resection of 25 cm of both ulnae. Defect in right ulna bridged by autogenous transplant from left ulna. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 11 A.

April 21, twenty-nine days. Animal sacrificed. Received injections of alizarin red intraperitoneally. Wounds healed per primam. Examination of femur showed animal was an adult dog.

Right ulna. Autogenous transplant in good position. Union with distal stump of ulna firm, with proximal stump fibrous. Over whole surface of transplant and the stumps of the ulna was an enormous amount of callous formation. About the transplant were areas of a thick gelatinous fluid suggesting mild infection.

Left ulna. Homogenous transplant in good position. United to stumps of ulna by fibrous tissue. Small amount of new bone formed on periosteal surface of transplant.

Experiment 12 A—Young dog. March 24, 1920.

Resection of 25 cm of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 12 B.

April 22, twenty-nine days. Animal sacrificed. Received injections of alizarin red intraperitoneally. Wound in right leg has sinus leading into deep fascia. Wound in left leg healed per primam. Examination of femur showed animal was a young dog.

Left ulna. Autogenous transplant in place surrounded by a mass of fibrous tissue. No signs of union with stumps but a good growth of new bone on all surfaces of transplant.

Right ulna. Homogenous transplant in place, surrounded by mass of mucin-like material. No signs of new bone formation.

Experiment 12 B—Old dog. March 24, 1920.

Resection of 25 cm of both ulnae. Defect in right ulna bridged by autogenous transplant. Defect in left ulna bridged by homogenous transplant from dog used in Experiment 12 A.

April 6, thirteen days. Animal died of peritonitis following injection of alizarin red. Wound in left leg open. Wound in right leg healed per primam. Examination of femur showed animal was an old dog.

Right ulna. Autogenous transplant in place. No union, but a small amount of new bone on middle of outer periosteal surface of transplant.

Left ulna. Homogenous transplant lost through the open wound.

Experiment 13 A—Adult dog. March 25, 1920.

Resection of 25 cm of both ulnae. Defect in left ulna bridged by autogenous transplant. Defect in right ulna bridged by homogenous transplant from dog used in Experiment 13 B.

April 24, thirty days. Animal sacrificed. Received injections of alizarin red intraperitoneally. Wound in right leg healed per primam. That in left leg had skin open but no discharge. Examination of femur showed animal was an adult dog.

Left ulna Autogenous transplant not found On distal stump of ulna was considerable callous formation, with fibrous tissue bridging defect No evidence of infection about bed of transplant

Right ulna Homogenous transplant in good position Firm fibrous union with stumps of ulna On marrow surface of transplant was a narrow border of new bone extending the full length of the transplant. On the lateral surface, which is the periosteal, there was a small amount of new bone at the ends of the transplant.

Experiment 13 B—Adult dog March 25, 1920

Resection of 25 cm of both ulnae Defect in right ulna bridged by autogenous transplant Defect in left ulna bridged by homogenous transplant from dog used in Experiment 13 A

April 2, eight days Animal dead in cage, cause not known Received one injection of alizarin red intraperitoneally Wounds healed per primam Examination of femur showed animal was an adult dog

Right ulna Autogenous transplant in place. Microscopic study shows normal staining of the cells in the greater part of the transplant. No regeneration found Duration of experiment was too short to determine definitely whether regeneration would have resulted

Left ulna Homogenous transplant in place Microscopic study shows greater part of transplant viable There was active regeneration of osteoid tissue from the marrow surface of the transplant

Experiment 14 A—Adult dog March 26, 1920

Resection of 25 cm of both ulnae Defect in left ulna bridged by autogenous transplant Defect in right ulna bridged by homogenous transplant from dog used in Experiment 14 B

April 24, twenty-nine days Animal sacrificed Received alizarin red Wounds healed per primam Examination of femur showed animal was an adult dog

Left ulna Autogenous transplant in good position United with stumps by fibrous tissue Only a small amount of new bone formed on proximal stump, with slight amount of new bone on proximal end of transplant.

Right ulna Homogenous transplant held in good position by firm fibrous union with stumps of ulna There was a small amount of new bone formed along the marrow surface of the transplant

Experiment 14 B—Adult dog March 26, 1920

Resection of 25 cm of both ulnae. Defect in right ulna bridged by autogenous transplant Defect in left ulna bridged by homogenous transplant from dog used in Experiment 14 A

April 4, nine days Animal found dead in cage, cause of death not known Examination of femur showed animal was an adult dog

Transplants not studied

Experiment 15 A—Old dog Feb 12, 1918

Resection of 4 cm. of shaft of right ulna Defect in bone bridged by a homogenous transplant of bone and periosteum removed from the shaft of femur of the dog used in Experiment 15 B

March 28, forty-four days Wound healed without infection Animal in good health Was given injections of sodium alizarin sulphonate twice each week. Sacrificed

Examination of the bones indicated that the animal was an old dog The homogenous transplant was removed from a young dog The transplant was in good position There was very little growth of bone from the stumps of

the resected bone. The transplant showed no evidence of regeneration of bone. There was, however, distinct evidence of absorption of the graft. The transplant was adherent to the surrounding tissues. Microscopic examination of the transplant showed no part of the transplant viable, and evident absorption of the transplant.

Experiment 15 B—Young dog Feb 12, 1918

Resection of 4 cm of shaft of ulna. Defect bridged by a transplant of bone and periosteum removed from the femur of the dog used in Experiment 15 A.

February 24, twelve days. Wounds healed without infection. Animal in poor health. Sacrificed. Examination of bones shows animal to be a young dog. The transplant in the defect in the ulna was removed from an old dog. The transplant was in good position. Gross and microscopic examination showed no evidence of regeneration of tissue from the transplant. There were no living cells in any part of the transplant.

Experiment 16 A—Old dog March 26, 1918

Resection of 4 cm of ulna with periosteum. Defect bridged by a homogenous transplant from the femur of adult dog used in Experiment 16 B.

April 18, thirteen days. Animal died from pneumonia. Wounds healed without infection. Examination of femur indicated that animal was an old dog. Microscopic examination of the transplant showed small areas on the marrow side of the transplant in which there was proliferation of cells apparently from the endosteum of the transplant. Also small sections of the periosteum were apparently viable. The transplanted cortical bone was apparently completely necrotic.

Experiment 16 B—Adult dog March 26, 1918

Resection of 4 cm of ulna. Defect bridged by a homogenous transplant removed from the femur of old dog used in Experiment 16 A.

June 4, seventy days. Animal in good health. Wounds healed without infection. Examination of bones indicated that animal was an old dog. The homogenous transplant was in good position. It is firmly united to the stumps of the resected bone. The transplant had increased very little in thickness. There was very little bone regeneration from the stumps of the resected bone. The defect was completely bridged by viable bone but the growth of bone from the transplant had been very slow.

Experiment 17 A—Adult dog Feb 4, 1918

Resection of 4 cm of right ulna with periosteum. Defect bridged by a homogenous transplant removed from femur of adult dog used in Experiment 17 B.

April 5, sixty days. Wounds healed without infection. Animal in good health. Sacrificed. Examination of femur indicated that the animal was an adult dog. The stumps of the resected bone were joined by a thin fibrous cord in which lay a thin remnant of the bone transplant. There was no evidence of regeneration from the transplant. It was obviously in process of being absorbed.

Experiment 17 B—Adult dog Feb 4, 1918

Resection of 4 cm of right ulna with periosteum. Defect bridged by a homogenous transplant from femur of adult dog used in Experiment 17 A.

April 5, sixty days. Wounds healed without infection. Animal in good health. Sacrificed. Femur showed animal to be an adult dog. The homogenous transplant was united to the stumps of the resected bone. There was regeneration of bone along the entire length of the transplant. The amount of growth of the graft was rather small.

Experiment 18 A—Adult dog Jan 9, 1917

Resection of 3 cm right ulna Bone transplant 3 cm long, 2 mm broad cut from full thickness of cortex of shaft of femur This transplant was used in Experiment 18 B The defect in the right ulna was bridged by a homogenous transplant removed from femur of dog used in Experiment 18 B

March 16, fifty-eight days Wounds healed per primam Animal given alizarin red intraperitoneally Dog died of peritonitis Examination of bones indicated that animal was an adult dog Very little regeneration of bone in the defect in the femur from which transplant for Experiment 18 B was removed

The homogenous transplant in the defect in the ulna was in good position The proximal end of graft was firmly united to the proximal stump of the resected bone There was no union between the distal end of the transplant and the distal stump of the resected ulna There was marked growth of bone from the proximal two thirds of the transplant None from the distal third There was very little bone growth from the proximal stump of the ulna

Experiment 18 B—Young dog Jan 9, 1917

Resection of 4 cm of right ulna Bone transplant with periosteum and endosteum removed from shaft of femur and used in Experiment 18 A Defect in right ulna was bridged by a homogenous transplant removed from dog used in Experiment 18 A

February 28, fifty days Wounds healed per primam Dog was given alizarin red intraperitoneally Sacrificed Examination of bones showed animal to be a young dog Defect in the femur from which transplant for Experiment 18 A filled by new bone

Homogenous transplant in defect in ulna in good position No evidence of any growth of bone from transplant The transplant was embedded in fibrous tissue to which it was intimately attached The transplant was clearly in process of absorption There was a large amount of bone regeneration from the stumps of the resected bone

Experiment 19 A—Old dog April 1, 1918

Resection of 4 cm of ulna Defect bridged by a homogenous transplant removed from the femur of old dog used in Experiment 19 B

June 4, sixty-four days, Animal in good condition Wounds healed without infection Sacrificed Examination of femur showed animal to be an old dog The homogenous transplant in the ulna defect was in good position It was firmly united to the proximal stump of the ulna The union of the transplant and the distal stump was fibrous The transplant was viable It was only very slightly increased in thickness

Experiment 19 B—Old dog April 1, 1918

Resection of 4 cm of ulna Defect bridged by a homogenous transplant removed from the femur of old dog used in Experiment 19 A.

April 8, seven days Animal died of pneumonia Wounds healed without infection Examination of bones indicated that animal was an old dog Transplant removed for microscopic study Microscopic examination showed areas in the transplant in which the cells stained in a normal manner There was no evidence of growth of tissue from the transplant

Experiment 20 A—Adult dog Feb 2, 1918

Resection of 4 cm of shaft of ulna The defect was bridged by a transplant of bone and periosteum removed from the femur of the dog in Experiment 20 B

May 15, 102 days Animal given injections of sodium alizarin sulphonate once each week Has remained in good health Sacrificed Examination of bones of dog indicated that the animal was an adult dog The transplant was in good position It was firmly united to the stumps of the resected bone There was growth of bone along the entire length of the transplant

Experiment 20 B—Young dog Feb 2, 1918

Resection of 4 cm right ulna with periosteum Defect bridged by a bone transplant removed from femur of adult dog used in Experiment 20 A

May 15, 102 days Wound healed without infection Animal in good health Examination of femur showed animal to be a young dog The homogenous transplant bridging the defect in ulna had completely failed to regenerate the defect. The graft was all absorbed except a small piece

Experiment 21 A—Adult dog March 20, 1919

Resection of 4 cm of shafts of both ulnae Defect in right ulna bridged by an autogenous transplant from left ulna Defect in left ulna bridged by a homogenous transplant from the ulna of dog used in Experiment 21 B

September 25, 189 days Wounds healed without infection No vital stain given Animal remained in good health Sacrificed Examination of femur indicated that animal was an adult dog

Right ulna Autogenous transplant The defect was entirely bridged by bone The transplanted area was very slightly smaller than the normal bone The junction of the transplant and distal stump of resected bone was plainly visible The junction of the transplant and the proximal stump could not be seen

Left ulna Homogenous transplant. Removed from adult dog The defect was completely bridged by bone The transplanted area was, however, approximately half the diameter of the normal bone. The junction of the transplant and the proximal stump was plainly visible

Experiment 21 B—Adult dog March 20, 1919

Resection of 4 cm of shafts of both ulnae Defect in right ulna bridged by autogenous transplant from left ulna Defect in left ulna bridged by a homogenous transplant from dog used in Experiment 21 A

August 8, 141 days Wounds healed without infection Vital stain given Animal died Examination of femur showed that animal was an adult dog

Right ulna Autogenous transplant in good position Firmly united to both stumps of resected bone Junctions of transplants and stumps of ulna distinct Transplanted area successfully repaired

Left ulna Homogenous transplant Removed from adult dog Graft in good position Firmly united to stumps of resected bone Transplanted area almost identical with that of right ulna

Experiment 22 A—Old dog Oct 30, 1919

Resection of 2.5 cm of both ulnae. Defect in left ulna bridged by autogenous transplant Defect in right ulna bridged by homogenous transplant from dog used in Experiment 22 B

April 17, 170 days Animal sacrificed Received injections of alizarin red Wounds healed per primam Examination of femur showed animal to be an old dog

Left ulna Autogenous transplant completely absorbed and its place filled by fibrous tissue.

Right ulna Homogenous transplant in position Solid union with distal stumps of ulna Proximal end of transplant slightly overlapped the proximal

stump of ulna and had a fibrous union. The defect was completely bridged by the bone, except for the fibrous union of the transplant and the proximal stump of the ulna.

Experiment 22 B—Young dog Oct. 30, 1919

Animal died of anesthetic during operation. Examination of femur showed animal to be a young dog.

Experiment 23 A—Adult dog March 6, 1919

Resection of 2.5 cm of shafts of both ulnae with periosteum. The defect in the right ulna was bridged by an autogenous bone graft from the segment of bone removed from the left ulna. The defect in the left ulna was bridged by a homogenous transplant taken from the ulna of dog used in Experiment 22 B.

October 16, 224 days. Wounds healed without infection. Animal has remained in good health. No vital stain given. Sacrificed. Examination, the femur indicated that the animal was an adult dog.

Right ulna. Autogenous transplant. Graft in fairly good position. Firmly united to the stumps of the resected bone. Junction with proximal stump still visible. No trace of junction between graft and distal stump. Defect completely regenerated.

Left ulna. Graft entirely absorbed. Ends of stumps of resected bone conical. Complete failure of transplant.

Experiment 23 B—Adult dog March 6, 1919

Resection of 2.5 cm of shafts of both ulnae. Defect in right ulna bridged by an autogenous transplant from the left ulna. Defect in left ulna bridged by a homogenous graft removed from dog used in Experiment 23 A.

October 16, 224 days. Wounds healed without infection. No vital stain given. Animal remained in good health. Sacrificed. Examination of the femur showed the animal to be an adult dog.

Right ulna. Autogenous transplant. Defect completely regenerated. Regeneration so perfect that little trace of previous operative procedure was visible.

Left ulna. Homogenous transplant removed from adult dog. Graft was in good position. United to both stumps of resected bone. Transplanted area slightly smaller than normal bone. The defect was completely regenerated, but not so perfectly as in the case of the autogenous transplant.

Experiment 24 A—Old dog Feb 15, 1919

Resection of 3 cm of both ulnae. Defect in right ulna bridged by an autogenous transplant removed from dog used in Experiment 24 B.

October 16; 243 days. Wounds healed without infection. Animal has remained in good health. No vital stain given. Sacrificed. Examination of bones indicated that animal was an old dog.

Right ulna. Autogenous transplant in good position. Firmly united to stumps of resected bone. Transplant apparently completely successful.

Left ulna. Homogenous transplant from old dog. Graft in good position. Firmly united to both stumps of resected ulna. The transplant was approximately the same size as the original bone at each end. The middle of the transplant was not so large as the original bone. The defect was apparently successfully repaired, but the growth of bone in the defect was not as marked as from the autogenous transplant.

Experiment 24 B—Old dog Feb 15, 1919

Resection of 3 cm of both ulnae. The defect in the right ulna bridged by an autogenous transplant from the left ulna. The defect in the left ulna was bridged by a homogenous transplant removed from dog used in Experiment 24 A.

BROOKS-HUDSON—BONE TRANSPLANTATIONS

October 16, 243 days Wounds healed without infection No vital signs given Sacrificed Examination of the femur indicated that the animal was an old dog

Right ulna Autogenous transplant The defect was completely regenerated The transplanted area was approximately the same size as the normal bone The site of union of the transplant with the distal stump was plainly visible There was no trace of the site of union of the transplant and the proximal stump of the ulna

Left ulna Homogenous transplant removed from old dog Defect was completely regenerated The area of transplantation was equal in size to the normal bone The junction of the transplant with the proximal stump was visible

Experiment 25 A—Young dog April 12, 1918

Resection of 2.5 cm of both ulnae. Transplant 6 cm long cut from shaft of femur One half of this transplant was used to bridge the defect in the right ulna The other half was used in Experiment 25 B The defect in the left ulna was bridged by a transplant removed from femur of dog used in Experiment 25 B

May 31, forty-nine days Animal dead Cause not known The wound on the right foreleg healed without infection There was a small discharging sinus in the operation wound of the left foreleg Animal was given vital signs Examination of the bones showed the animal to be a young dog

Right ulna The autogenous transplant was in good position It was firmly united to the distal stump of the ulna The union to the proximal stump was fibrous There was growth of bone from both stumps of the ulna and along the entire length of the transplant

Left ulna The homogenous transplant was in good position There was a cavity at each end of the graft containing purulent fluid There was a large amount of new bone formation from the transplant The infection had apparently not extended along the transplant but was localized to the ends of the transplant

Experiment 25 B—Old dog April 12, 1918

Resection of 3 cm of both ulnae Transplant 6 cm long cut from the shaft of the femur One half of this transplant was used to bridge the defect in the right ulna The other half was used in Experiment 25 A The defect in the left ulna was bridged by a transplant removed from the femur of dog used in Experiment 25 A

Jan 22, 1919, 285 days Animal in good condition Wounds healed without infection Sacrificed Examination of the femur indicated that the animal was an old dog

Right ulna The autogenous transplant had completely disappeared The stumps of the resected ulna were conical There was a defect measuring 2 cm

Left ulna The homogenous transplant had completely regenerated the defect The area of regeneration was equal in size to the stumps of the resected bone

Experiment 26 A—Adult dog April 9, 1919

Resection of 3 cm of both ulnae Bone graft 6 cm long, 2 mm wide removed from the shaft of the femur Periosteum preserved in the bone transplant One half of the transplant was used to bridge the defect in the left ulna The other half of the transplant was used in Experiment 26 B The defect in the right ulna was bridged by a transplant from the femur of the dog used in Experiment 26 B

April 19, ten days Animal died of infection in thigh wound Wounds on both forelegs healed without infection

Microscopic examination showed both the autogenous and homogenous transplants apparently completely necrotic. There was no demonstrable difference in reaction about the transplants

Experiment 26 B—Old dog April 9, 1918

Resection 3 cm of both ulnae Transplant of bone and periosteum 6 cm long removed from shaft of femur One half of this transplant used to bridge defect in the left ulna The other half was used in Experiment 26 A The defect in the right ulna was bridged by a transplant from the femur of adult dog in Experiment 26 A

Jan 23, 19, 290 days Animal in good condition Wound healed without infection Sacrificed Examination of bones showed the animal to be an old dog

Left ulna The autogenous transplant was in perfect condition The defect in the ulna was completely regenerated The area of regeneration was larger than the contiguous stumps of the resected bone

Right ulna The homogenous transplant was in perfect position The defect was completely regenerated The area of transplantation was equal in size to the distal stump of the resected bone This stump of bone had, however, decreased markedly in size The regenerated area was much smaller than the proximal stump of the ulna

COMMENT

In the discussion of the results of these experiments only those experiments in which the experimental animals lived long enough to determine definitely the presence or absence of bone regeneration are considered

These experiments show conclusively that a transplant of bone with the periosteum and marrow surfaces intact removed from one dog and placed in a defect in the shaft of a bone of another dog may result in a complete regeneration of the defect The transplant in such instances remains in whole or part viable and is the source of bone regeneration Experiments 23 B, 24 A, 24 B, 25 B and 26 B show the bone defect completely regenerated at the end of periods of seven and nine months In Experiment 25 B, in which the animal was sacrificed 285 days after the transplantation, the repair of the defect was so perfect it is difficult to believe otherwise than that the defect is permanently repaired In the study of the homogenous transplants of shorter duration it was clear that the transplant was the source of new bone formation Whether the defect is permanently repaired by cells regenerated from the transplant or whether these cells are subsequently replaced by cells derived from the host is not clear

The comparison of the proportions of success and failure of the autogenous transplants and the homogenous transplants is of particular interest It will be noted in Table 2 that the percentage of instances in which bone regeneration took place from the homogenous transplants was not strikingly lower than that from the autogenous transplants Furthermore in thirteen experiments in which the duration of the experiment was longer than three months the homogenous transplants

TABLE 1—SUMMARY OF EXPERIMENTS

Exper No	Age of Dog	Duration of Experiment Days	Results of Autogenous Transplant	Source of Homogenous Transplant	Age of Donor	Results of Homogenous Transplant	Remarks
1 A	Young	12	+++	1 B	Young	+++	Slight infection autogenous transplant
1 B	Young	30	+++	1 A	Young	0	Homogenous transplant completely absorbed
2 A	Young	7	—	2 B	Adult	?	Duration of experiment too short
2 B	Adult	45	+	2 A	Young	—	Homogenous transplant infected
3 A	Young	23	+++	3 B	Young	+++	
3 B	Young	23	+++	3 A	Young	+++	
4 A	Young	29	+	4 B	Adult	+	
4 B	Adult	34	+++	4 A	Young	0	Homogenous transplant completely absorbed
5 A	Young	29	+++	5 B	Old	+	
5 B	Old	0	—	—	—	—	Died of anesthetic
6 A	Young	36	+++	6 B	Old	++	
6 B	Old	0	—	—	—	—	Died of anesthetic
7 A	Young	19	+	7 B	Young	+++	
7 B	Young	34	+	7 A	Young	+++	
8 A	Adult	33	++	8 B	Adult	++	
8 B	Adult	18	—	8 A	Adult	++	Both wounds infected
9 A	Old	18	0	9 B	Young	+++	
9 B	Young	30	++	9 A	Old	+++	
10 A	Young	30	+++	10 B	Adult	+	
10 B	Adult	30	+	10 A	Young	0	
11 A	Young	14	+++	11 B	Adult	++	
11 B	Adult	29	+++	11 A	Young	+	Autogenous transplant slightly infected
12 A	Young	29	+++	12 B	Old	—	Mild infection about homogenous transplant
12 B	Old	13	+	12 A	Young	—	Homogenous transplant infected
13 A	Adult	30	0	13 B	Adult	+	
13 B	Adult	8	?	13 A	Adult	+++	
14 A	Adult	29	+	14 B	Adult	—	
14 B	Adult	9	—	14 A	Adult	—	Transplant not examined
15 A	Old	44	—	15 B	Young	0	
15 B	Young	12	—	15 A	Old	0	
16 A	Old	13	—	16 B	Adult	+	
16 B	Adult	70	—	16 A	Old	++	
17 A	Adult	60	—	17 B	Adult	0	
17 B	Adult	60	—	17 A	Adult	+	
18 A	Adult	58	—	18 B	Young	++	
18 B	Young	50	—	18 A	Adult	0	
19 A	Old	64	—	19 B	Old	++	
19 B	Old	7	—	19 A	Old	?	
20 A	Adult	102	—	20 B	Young	+++	
20 B	Young	102	—	20 A	Adult	0	
21 A	Adult	189	+++	21 B	Adult	++	
21 B	Adult	141	+++	21 A	Adult	+++	
22 A	Old	170	0	22 B	Young	++	
22 B	Young	0	—	—	—	—	Died of anesthetic
23 A	Adult	224	+++	23 B	Adult	0	
23 B	Adult	224	+++	23 A	Adult	++	Autogenous transplant more perfect
24 A	Old	243	+++	24 B	Old	+++	Autogenous transplant more perfect
24 B	Old	243	+++	24 A	Old	+++	Homogenous transplant more perfect
25 A	Young	49	+++	25 B	Old	+++	
25 B	Old	285	0	25 A	Young	+++	
26 A	Adult	10	0	26 B	Old	0	
26 B	Old	290	+++	26 A	Adult	++	

TABLE 2—RESULTS OF TRANSPLANTATIONS

		Success	Failure	Per Cent Success
Total number transplants	76	61	15	80.2
Autogenous transplants	33	28	5	84.8
Homogenous transplants	43	33	10	76.8

resulted in actually a larger percentage of successful regenerations of the bone defects than the autogenous transplants. This indicates that the survival and growth of the transplant is not merely temporary. In thirty-one experiments the results of both autogenous and homogenous transplants were observed in the same animals for the same periods of time. In one instance both the autogenous and homogenous transplants failed. In four instances the autogenous transplant alone failed. In five instances the homogenous transplant alone failed. In the remaining twenty-one instances, in which there was growth of bone from both transplants, there was no noticeable difference in the amount of growth of bone from the two transplants in ten experiments. In eight instances the autogenous transplants regenerated more bone, and in three instances the homogenous transplants grew better. It would seem, therefore, that homogenous transplants of bone are less likely to succeed than autogenous transplants, but that there is no indication that homogenous transplants grow for a time and then

TABLE 3—RESULTS OF AUTOGENOUS TRANSPLANTS

Age	Number	Success	Failure	Per Cent Success
Young	14	14	0	100
Adult	12	10	2	83
Old	7	4	3	57

become absorbed. Furthermore, the relative percentages of success of the autogenous and homogenous bone transplants are not strikingly different.

The influence of the ages of the experimental animals on the proportions of success and failure of the autogenous transplants is clearly shown in Table 3. These results in the autogenous transplants correspond exactly with our previous experience. There was no instance in which regeneration did not take place from an autogenous transplant in a young animal in which wound infection did not occur. In the old animals the percentage of instances in which regeneration from the autogenous transplant was found decreased to 57 per cent. The autogenous transplants served as a control of the method of experimental study of the homogenous transplants, since both types of transplants were similarly placed in the same animals and the results observed at the same intervals of time.

The relative ages of the donors and recipients of the homogenous transplants is shown in Tables 4, 5 and 6. In Table 4 the number of different combinations of ages of donors and recipients is so large that the number of experiments in each combination is small. The per-

centage of success of the homogenous transplants in the various combinations of ages of donor and recipient is strikingly equal in all the various combinations except in the groups of old donor-adult recipient (50 per cent), adult donor-old recipient (100 per cent) and old donor-old recipient (100 per cent). In these groups the number of experiments in each was small. In Table 5 the ages of the donors independent of the ages of the recipients is shown. It will be noted that the young donors gave a smaller proportion of successful homogenous

TABLE 4—RESULTS OF HOMOGENOUS TRANSPLANTS IN THE VARIOUS COMBINATIONS OF AGES OF DONORS AND RECIPIENTS

Donor	Recipient	Number	Success	Failure	Per Cent Success
Young	Young	6	5	1	83
Adult	Young	5	4	1	80
Old	Young	5	4	1	80
Young	Adult	5	3	2	60
Adult	Adult	11	9	2	81
Old	Adult	2	1	1	50
Young	Old	4	3	1	75
Adult	Old	2	2	0	100
Old	Old	3	3	0	100

TABLE 5—RESULTS DONORS OF DIFFERENT AGES

Donors	Number	Success	Failure	Per Cent Success
Young	15	11	4	73
Adult	18	15	3	83
Old	10	8	2	80

TABLE 6—RESULTS RECIPIENTS OF DIFFERENT AGES

Recipients	Number	Success	Failure	Per Cent Success
Young	16	13	3	81
Adult	18	13	5	72
Old	9	8	1	80

transplants than the adult or old donors. The percentages of successful homogenous transplants from the three age groups, however, is not strikingly different. In Table 6 the experiments are grouped according to the ages of the recipients of the homogenous transplants independent of the ages of the donors. It will be noted that the adult recipients showed the smallest proportion of successful results. The difference is not great, but the number of experiments in each group is sufficiently large to be indicative of a possible age influence on homogenous transplantation of bone in dogs. It would seem, however, that the age influence was not the most important factor, and that

it was more often other factors of incompatibility of host and transplant which determined the success or failure of the transplant to survive and grow

In transplantation of tissue two groups of factors always influence the transplants

One group of factors has to do with the transplant and the other with the reaction of the bed into which it is placed. In autogenous transplantation of bone as carried out in these experiments in which the bone grafts were placed in a defect in the shaft of a bone, the external influences are certainly the most favorable for the survival and growth of the transplant, since the transplant is taken from the same individual and placed in a site in which bone is normally present and exercises its normal functions. It is, therefore, certainly reasonable to believe that with autogenous transplants placed in such favorable environments, the success or failure of the transplant would depend largely on the internal factors alone. The age of the animal is certainly an important factor in determining the relative regenerative powers of bone, and therefore in determining the regenerative powers of a transplant of bone.

In the homogenous transplantations of bone as carried out in these experiments the influences as regards "functional demand" were the same as in the autogenous transplants. The age influence on the power of regeneration of the transplants independent of their environment must be assumed to have been the same in both types of transplants. In the homogenous transplants the incompatibility of tissues of different individuals was a factor which was not present in the autogenous transplants. From the results obtained in these experiments it would seem that this factor was more important than the age factor in determining the success or failure of the transplant.

That the age of the donor must influence the intrinsic power of growth of a bone transplant would seem to be a conclusion unavoidable. Also the capacity of the recipient to react to the presence of a foreign tissue must vary with the age of the individual, probably being least in the very young and old, and greatest in the adult. The direct demonstration of the truth of these assertions is obviously impossible, as any experiment is an inseparable combination of donor and recipient, each with its many varying properties. The experiments described in this paper are incomplete in that very young and very old animals were not used. No experiments were carried out on animals which were related. Also the experimental method was such that only the results of the transplantations as regards actual new bone formation were observed. No study of the reactions of the beds of the transplants was made.

The experiments do show conclusively, however, that the influence of the age either of the donor or recipient was not of sufficient importance to manifest itself in a considerable number of experiments. The ages of the animals were of sufficient range and the experimental method was suitable to determine the practical application of homogenous bone transplantation.

Further experimental study of homogenous bone transplants as regards the reaction of the tissues of the host to the transplant in animals of varying age and relationship will be interesting. It would seem that bone would be a particularly suitable tissue for the study of homogenous transplantation, since it is less specialized and regenerates more readily than glandular tissue, and it is a tissue which is easily recognized by macroscopic, microscopic, and vital staining methods. It is possible that it could be determined by preliminary tests whether a homogenous bone transplant would succeed or fail. In a considerable number of the experiments described in this paper the red blood corpuscles and the blood serums of the animals were tested for the presence of iso-agglutinins and hemolysins. None were demonstrated by routine clinical methods. It should be borne in mind that blood transfusions and homogenous transplantations of tissue are not similar procedures, as in the former material which has no regenerative powers is transplanted while in the latter the host must do more than simply tolerate the alien tissue. It is probable that the success of homogenous transplantation of tissues is entirely independent of blood groups, since Loeb¹⁰ has shown that relationship of animals has an important influence on the results of homogenous transplantation of tissue, and Happ¹¹ and others have shown that relationship has no influence on blood groups.

CONCLUSIONS

1 A defect in the shaft of a bone of a dog may be permanently regenerated by a bone transplant removed from another dog.

2 Homogenous transplants of bone were successful in 76.8 per cent of instances as compared with 84.8 per cent of successful results in autogenous transplants.

3 The age of the animals is an important factor in determining the proportion of success and failure of autogenous transplants of bone in dogs.

4 The importance of the age of the donor or recipient as a factor in determining the success or failure of the homogenous transplant of bone in a dog is probably of less importance than factors of incompatibility of tissue of different individuals.

10 Loeb, L. J. M. Res. **39** 39 (Sept.) 1918.

11 Happ, W. M. J. Exper. Med. **31** 313 (March) 1920.

GALLBLADDER DISEASE

A STATISTICAL STUDY

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Next to appendicitis, gallbladder disease is probably the commonest intra-abdominal lesion. This is evidenced both by the reports of operative procedure and by necropsy statistics. Mitchell,¹ in 1918, reporting the gallstone incidence in 1,600 necropsies of all ages, gave a comprehensive report of 122,808 postmortems from American and European sources. Among them were 7,022 gallstone cases, or an average of 5.7 per cent. In 1914, Hesse² in a somewhat similar report found 4,848 gallstone cases, or 6 per cent in 80,802 postmortems. The usual age at which the necropsy was performed in this latter series was 60-70 years. It is interesting to note that among these 4,848 cases in only 16 per cent there were symptoms referable to gallstones.

In accepting such figures one must consider (1) that they concern for the most part elderly people in whom cholelithiasis or gallbladder disease is more to be expected, (2) that they comprise mainly the working classes rather than the more well-to-do, well nourished class in whom gallbladder lesions are more common, (3) that they include those only in whom gallstones were taken as evidence of gallbladder disease, (4) that coming from pathologic reports from public institutions, the histories undoubtedly are rather incomplete, (5) that they consider the incidence of gallstone disease in those dying from all causes and do not represent the average sick case.

W J Mayo,³ in 1,244 cases in which operation was performed for uterine myoma, found incidentally ninety-two cases, or 7.2 per cent of gallstones, and Peterson⁴ in Ann Arbor, reported 135 cases of gallstones, 12.5 per cent, in 1,056 cases which came to operation for definite gynecologic lesions. Naunyn in his original work remarks that about 10 per cent of the human race have gallstones. W J Mayo thinks this rather high and conservatively remarks that about 0.5 per cent would be more nearly the correct incidence.

1 Mitchell, L. J. Incidence of Calculi in the Gallbladder as Met with in 1,600 Necropsies, *Ann Surg* **68** 289 (Sept.) 1918

2 Hesse, E. R. Frequency of Gallstones, *Russk. Vrach* **13** 289, 1914

3 Mayo, W J, Innocent Gallstones a Myth, *J A M A* **56** 1021 (April 8) 1911

4 Peterson, Reuben. Gallstones During the Course of 1,066 Abdominal Sections for Pelvic Disease, *Surg, Gynec & Obst.* **20** 284, 1915

During the six years since the opening of the Peter Bent Brigham Hospital an increasing number of gallbladder cases have been admitted to the surgical service, in all 470, or 41 per cent, of the 11,622 surgical admissions. Of these, 397 came to operation, or 42 per cent, out of a total of 9,484 operations. A study of this series of gallbladder cases in a statistical manner forms the subject of this paper.

INCIDENCE OF GALLBLADDER DISEASE

Most writers on gallbladder disease have noted the great preponderance of the disease in the female sex as contrasted with the male. From necropsy reports, Mitchell found a ratio of 3 to 1, and Hesse, of 7 to 1. From operative statistics, Mayo,³ in his series of 4,000 cases, found 3,075 female cases and 925 male. Hubbard and Kimpton,⁵ in the Boston City Hospital series of 400 cases, reported a ratio of 3 to 1. Rhodes,⁶ in 172 cases, found a ratio of 3 to 1. Deaver,⁷ in his 1914 report, dividing gallbladder diseases into three classes, (1) simple

TABLE 1—INCIDENCE OF GALLBLADDER DISEASE BY AGE AND SEX

Decade	Number of Cases			Percentage		
	Male	Female	Total	Male	Female	Total
0-10	0	0	0	0	0	0
11-20	2	3	5	0.5	0.8	1.3
21-30	5	43	48	1.26	10.8	12.0
31-40	21	78	99	5.3	19.7	25.0
41-50	24	82	106	6.0	20.6	26.6
51-60	18	79	97	4.5	20.0	24.5
61-70	9	27	36	2.3	6.8	9.1
71-80	3	3	6	0.75	0.75	1.5
Total	82	315	397	20.6	79.4	100.0

cholecystitis with or without stones, (2) cases with common duct involvement, and (3) cases with secondary pancreatic involvement, found a ratio of 5 to 1 in the first simple group, decreasing to 2.2 to 1 in the second and third groups. In the Brigham series of 397 cases, there were 315 female cases and eighty-two male cases, a ratio of 4 to 1. This preponderance has been ascribed to various conditions, among which may be noted (1) the sedentary habit of women, (2) the poor muscle tone with ptosis of abdominal walls and organs, causing kinking of the extrahepatic ducts, (3) the frequency of pelvic infection with blood stream extension, (4) the mechanical effect of the

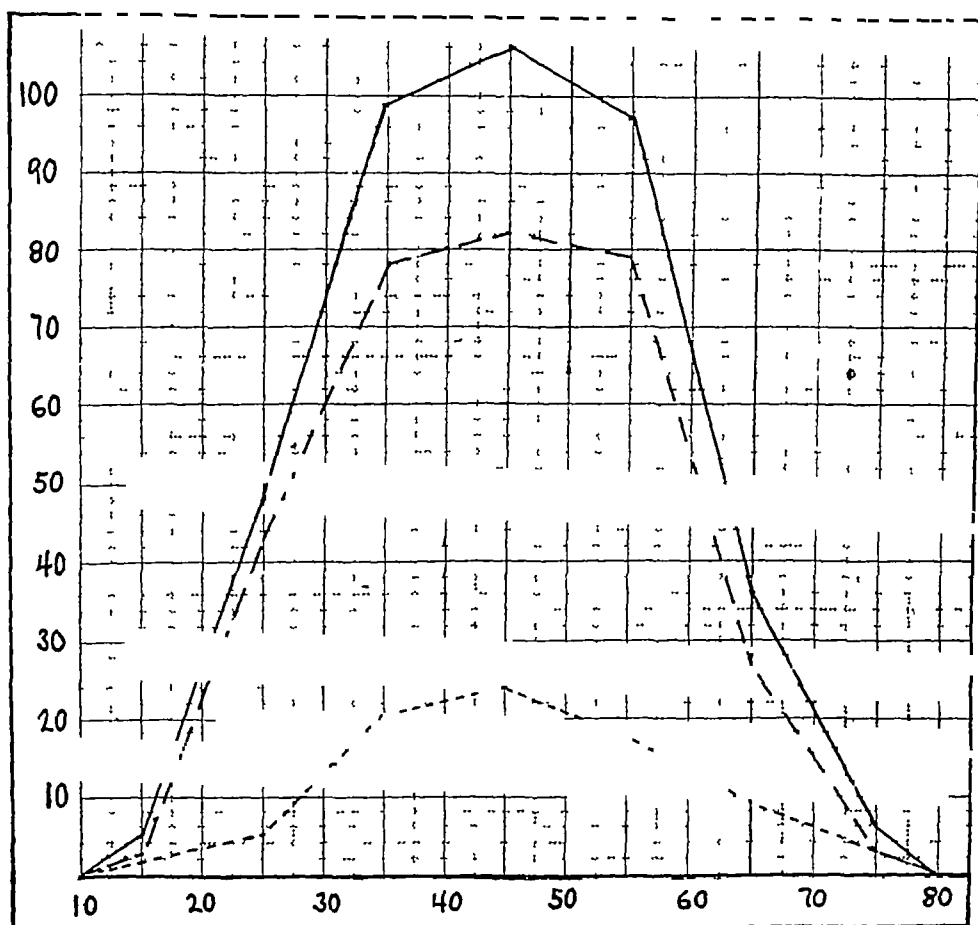
5 Hubbard, J. C., and Kimpton, A. R. Gallstones, A Statistical Study of Cases Occurring at Boston City Hospital, *Ann Surg* 61 535, 1915.

6 Rhodes, R. L. Observation in 133 Cases of Gallbladder Surgery with Special Reference to Postoperative Treatment, *Surg., Gynec & Obst* 23 399, 1916.

7 Deaver, J. B. A Report of the Cases of Gallstone Diseases Operated on During the Year 1914. *Ann Surg* 62 197, 1915.

enlargement of the uterus during pregnancy, (5) the supposed hypercholesterinemia, and (6) the concentration and inspissation of bile during pregnancy

Gallbladder disease is essentially a disease of middle age. Undoubtedly many lesions originate early in life but remain dormant or produce indefinite minor or vague symptoms until middle age. It occurs with increasing incidence with the advancing decades, the greatest frequency being between 40 and 50 years of age. Table 1 gives the incidence



Curve of incidence solid line, total, broken line, female, dotted line, male

according to the decades of this series. It shows a total of 76.1 per cent occurring between the ages 31 and 60, with the highest percentage (26.6 per cent) occurring in the fifth decade. The accompanying chart shows the curve of incidence. Gallbladder disease is considered rare below 20 years of age. Mayo, in 4,000 cases, recorded forty-one under 20 years of age, three of them being males. Babcock,⁸

⁸ Babcock, W. W. Cholecystectomy and Cholecystic Toxemia, J. A. M. A. 65:1428 (Oct. 23) 1915.

reported one of 14 and one of 4 years of age Buchanan,⁹ in 300 cases, described one of 5 and one of 19 years of age Kimpton, in 400 cases, reported one of 16 years of age In this series there were five below 19 years of age of which brief mention will be made

REPORT OF CASES IN EARLY LIFE

CASE 1—A schoolgirl, 19 years of age, with recurring attacks of sharp pain lasting from fifteen to twenty minutes in right lower abdomen, some nausea and vomiting, which were aggravated by eating, was referred to the hospital for appendicitis Operation showed two large gallstones in the gallbladder, which was the seat of chronic cholecystitis Cholecystectomy and appendectomy were performed (S 5128)

CASE 2—A schoolgirl, aged 14, complained of repeated attacks of jaundice when a young girl During the preceding eleven months there were recurrent attacks of pain, mainly in the upper abdomen, radiating to the back and shoulder, but with no nausea or vomiting, and only slight jaundice There was abdominal tenderness after these attacks Operation showed old pericholecystic adhesions and a shrunken gallbladder with many stones Cholecystectomy and appendectomy were performed (S 5515)

CASE 3—A schoolgirl, 17 years of age, gave a history of two attacks during the preceding three months of crampy, colicky, right lower abdominal pain with no nausea or vomiting, in the first attack there was radiation of pain to back and shoulder, fever and abdominal tenderness Operative findings disclosed a normal pelvic appendix and a large distended gallbladder with four large stones Cholecystostomy and appendectomy were performed (S 8215)

CASE 4—A boy, 17 years of age, was first admitted to the hospital with a history of severe crampy colicky pain, starting in the upper abdomen and later becoming diffuse Occasionally the pain radiated to the right upper quadrant, there were marked nausea, vomiting and severe constipation He was therefore referred to the hospital for intestinal obstruction The findings were essentially negative except for a rise in temperature to 100 F and a white blood cell count of 17,000, immediately becoming normal Relief was obtained by enemas German measles developed, and the patient was later discharged Twenty-four hours after discharge, he reentered with very severe excruciating pain in the upper abdomen radiating to back and shoulder, and tenderness under the right costal margin His temperature was 99 F., pulse rate 80, the white blood cell count 13,000 Operation showed an acute inflammatory gallbladder, thick-walled, with mural abscesses and gallstones Cholecystectomy and appendectomy were performed (S 9183)

CASE 5—A schoolboy, 13 years of age, was referred to the hospital for upper abdominal pain, diffuse, with occasional acute exacerbations during the preceding six days Examination revealed moderate tenderness in the upper abdomen, some jaundice, a temperature of 100.6 F and a white blood cell count of 8,000 Operation showed a subacute cholecystitis, but no stones Cholecystectomy was performed (S 9580)

⁹ Buchanan, J J End-Result of a Series of 300 Operations on the Gallbladder, Surg, Gynec. & Obst 21 499, 1915

One can infer from the incidence by decades that gallbladder disease is more frequent in the married than in the single woman. W J Mayo found that 90 per cent of gallbladder diseases in the female occurred in married women, and that about 90 per cent of these had borne children. Rhodes found 88.3 per cent and Peterson 84 per cent. Deaver remarks that four fifths of all gallbladder cases occur in married women. In this series, 88.6 per cent of all female cases were in married women, and of these 87 per cent had passed through one or more pregnancies. There were only thirty-six single women among the 315 female cases. Table 2 shows the incidence by decades in married and unmarried women, and shows the relation of the increasing number of pregnancies to the frequency of gallbladder disease.

TABLE 2—INCIDENCE OF GALLBLADDER DISEASE BY DECADRS IN RELATION TO MARRIAGE AND PREGNANCY

Decade	Number of Cases			Percentage		Children		Percentage		Average No of Children
	Total	Single	Married	Single	Married	Without	With	Without	With	
10-20	3	3	0	100.0	0	0	0	0	0	0
21-30	43	2	41	4.6	95.4	7	34	17.0	83.0	2.2
31-40	76	5	71	6.6	93.4	11	60	15.5	84.5	3.7
41-50	88	11	77	12.5	87.5	5	72	6.5	93.5	4.3
51-60	74	8	66	10.8	89.2	9	57	13.6	86.4	3.9
61-70	28	5	23	17.0	83.0	6	17	26.0	74.0	3.3
71-80	3	1	2	33.0	67.0		2		100.0	2.0
Total	315	35	280			38	242			

ETIOLOGY OF GALLSTONES

Galippe,¹⁰ in 1886, was the first to advance the bacterial origin of lithiasis in general. To Gilbert,¹¹ however, belongs the credit for definitely demonstrating the infectious origin of cholelithiasis. His experiments, together with those of his associates, beginning in 1890, were largely responsible and formed the foundation of Naunyn's theory of bacterial origin of gallstones which the latter propounded at the Congress of Wiesbaden in 1891. Welch,¹² in 1890, had demonstrated the presence of *Bacillus coli* and *Staphylococcus pyogenes* in gallstones and suggested that they might be a nucleus for their for-

10 Galippe, V. Mode de formation du tartre et des calculs salivaires, considerations sur la production des calculs en general, presence des microbes ou de leurs germes dans ces concrections, Jour des connaissances med (25 mars) 1886, Compt rend Soc de biol, Series 8, 3 116, 1886.

11 Gilbert, A. Note pour service a l'histoire de la theorie microbienne de la lithiase biliaire, Arch gen de med 2 257, 1898.

12 Welch, W H, quoted by Moynihan, B G A. Gallstones and Their Surgical Treatment, Ed 2, Philadelphia, W B Saunders Company, 1905.

mation Blachstein¹³ and Welch,¹⁴ in 1891, noted the constant occurrence of bacilli in the gallbladder in cases of animals experimentally inoculated with colon and typhoid organisms. In 1893, Gilbert and Dominici¹⁵ noted several small concretions in the gallbladder in experimentally produced cholecystitis in rabbits and, in January, 1897, they produced definite gallstones in the gallbladder of dogs by inoculation of colon bacilli. In May, 1897, Mignot¹⁶ produced stones in the gallbladder of guinea-pigs in a similar manner. Gilbert and Fournier¹⁷ produced, in 1897, definite biliary calculi in rabbits, by the inoculation of typhoid bacilli. Mignot, after a long series of experiments, concluded that the chief elements in gallstone formation were (1) the presence of an attenuated organism of almost any variety, and (2) a stasis of the bile current to allow for the accumulation of precipitated material. Virulent organisms produced an acute cholecystitis and were not favorable for the production of gallstones. That gallstones could be produced experimentally has been verified by Cushing,¹⁸ Richardson¹⁹ and other investigators. The organisms producing them included *Bacillus coli*, *Bacillus typhosus*, *Staphylococcus pyogenes*, *Streptococcus pyogenes*, *Bacillus subtilis* and *pneumococcus*. Naunyn,²⁰ in putting forth the bacterial theory of gallstone formation, concluded that cholesterol was not a specific secretion from the liver but that the source of cholesterol in gallstone formation was from the degenerated, desquamated epithelial cells of the gallbladder wall and bile ducts, these changes being produced by a mild inflammation of bacterial origin, the so-called "lithogenous catarrh" of Naunyn. Aschoff and Bacmeister²¹ showed that the glands of Luschka were in reality

13 Blachstein, A. G. Intravenous Inoculation of Rabbits with *Bacillus Coli Communis* and the *Bacillus Typhi Abdominalis*, Johns Hopkins Hosp Bull 2 96, 1891.

14 Welch, W. A. Additional Note Concerning the Intravenous Inoculation of *Bacillus Typhi Abdominalis*, Johns Hopkins Hosp Bull 2 121, 1891.

15 Gilbert and Dominici. Angiocholite et cholecystite typhiques experimentales, Comptes rend Soc de biol 5 1033 (Dec 23) 1893.

16 Mignot, quoted by Hartman, M. H. Pathogenese de la lithiase, Presse med 3 (2 mars), 1898, L'origine microbienne des calculs biliaires, Arch gen de med 2 129, 1898.

17 Gilbert and Fournier. Lithiase biliaire experimentale, Comptes rend Soc. de biol 936 (Oct 30) 1897.

18 Cushing, Harvey. Observation upon the Origin of Gallbladder Infection and upon the Experimental Formation of Gallstones, Johns Hopkins Hosp Bull 10 166, 1899.

19 Richardson, M. W. On the Role of Bacteria in the Formation of Gallstones, J Boston Soc. Med Sc. 3 79, 1899.

20 Naunyn, Bernard. Die Gallensteinkrankheiten, Verhandl d Cong f inn Med 10 17, 1891, compare, Naunyn, Bernard. A Treatise on Cholelithiasis, New Sydenham Soc 158 1896.

21 Aschoff and Bacmeister. Die Cholelithiasis, Jena, 1909.

epithelial lined clefts or crypts in the gallbladder wall which under infection became greatly dilated, deepened and tortuous and filled with products of inflammation. Organisms surviving in the hidden passages of these clefts accounted for the reinfection of the gallbladder with reappearance of gallbladder symptoms. Cholesterol crystals and calculi could be seen in all stages of formation in these clefts. As a result of the infection, the bile salts were destroyed and the cholesterol, held in solution by virtue of biliary salts, was precipitated about the degenerated cells as a nucleus.

Rovsing²² maintained that the chief cause of lithiasis was a concentration and inspissation of the bile during febrile states and pregnancy, calcium and, later on, bile salts being precipitated and forming a nucleus for the accumulation of cholesterol crystals. These facts were supported by the chemical analysis of the stones in their early state of formation and by the high percentage of cases in which the bile was found sterile on culture. He believes that the formation of stones always preceded the infection and that infection might subsequently follow from the irritation of the calculus as a foreign body.

Granting the infectious theory as the more plausible, there are three general routes of infection: (1) ascending infection from the duodenum to common and cystic ducts into the gallbladder, (2) descending infection through the portal system into the liver and through the bile ducts into the gallbladder, and (3) the vascular or hematogenous route. The first of these is highly improbable because of the almost continuous current of bile towards the duodenum and also on account of the great difficulty, from anatomic conditions, of producing an efflux from the duodenum into the gallbladder. The first two are also rather improbable because they presuppose infection from the mucous membrane side of the gallbladder. Mucous membrane, however, is well constructed for surface protection and very resistant to such infection. Rosenow²³ has given special emphasis to the hematogenous method. He believes that gallstones are one of the results of cholecystitis, that cholecystitis is caused by the bacterial invasion of the gallbladder wall, septic infarcts of the capillaries being found in the base of the mucous membrane which result in areas of necrosis, either local or general. He believes in the specificity of infecting or invading organisms—a selective localization of the infection. Organisms developing in a

²² Rovsing, T. Studier over Galdestenenes Patogenese, Hospitalstidende 8 249, 1915.

²³ Rosenow, E. C. Bacteriology of Cholecystitis and Its Production by Injection of Streptococci, J. A. M. A. 63 1835 (Nov. 21) 1914. The Etiology of Cholecystitis and Gallstones and Their Production by the Intravenous Injection of Bacteria, J. Infec. Dis. 19 527 1916.

special organ or tissue have their properties so modified by this special environment that when introduced into another host they select this special tissue or organ and produce their specific lesions in that definite area. By his special technic, he has been able to get in cases of cholelithiasis and cholecystitis, a high percentage of cultures from bile, gallbladder wall, calculi and the draining lymph glands, and has been able to reproduce the gallbladder lesions by introducing the organisms intravenously into animals. Deaver has noted the association of appendicitis with cholecystitis and infers that the appendix may act frequently as a primary focus of infection.

More recently Henes²⁴ has contended that, while infection may play a rôle in gallstone formation, while bacterial growth may alter the chemical composition of the bile, and while inflammation of the mucous membrane may produce epithelial desquamation for gallstone formation, after all a condition of hypercholesterinemia is the primary and fundamental etiologic factor in gallstone formation. A large number of gallbladders with stones, particularly the cholesterol stones, according to him, show no evidence of infection. He reports thirty-eight cases of cholelithiasis, all showing a definite hypercholesterinemia, and suggests the use of cholesterol determinations as a valuable diagnostic adjunct. He infers that such cases have a definite diathesis which may evidence itself in many ways, such as arteriosclerosis, gallstones, nephritis, etc. Aoyama's²⁵ experimental work in producing gallstones or concretions similar to gallstones by subcutaneous injection or by oral feeding of cholesterol or its esters appears to give some support to his views.

Galindez²⁶ still more recently disputes the value of cholesterol determination in gallbladder diagnosis. He has found no constant hypercholesterinemia, even in those cases in which the liver function has been seriously interfered with. In cases of catarrhal icterus he has found normal cholesterol content. In a large number of common lesions unrelated to gallbladder or liver functions, such as appendicitis and pulmonary tuberculosis, he has found various grades of hypocholesterinemia and hypercholesterinemia. Rothschild and Rosenthal²⁷ found a general hypercholesterinemia associated with cholelithiasis. Many cases of cholelithiasis with positive findings at operation

24 Henes, Edwin, Jr. The Value of the Determination of the Cholesterol Content of the Blood in the Diagnosis of Cholelithiasis, *J. A. M. A.* **63** 146 (July 11) 1914, *Surg., Gynec. & Obst.* **23** 91, 1916.

25 Aoyama. Experimenteller Beitrag zur Frage der Cholelithiasis, *Deutsch. Ztschr. f. Chir.* **132** 234, 1914.

26 Galindez, A. The Importance of Hypercholesterinemia in Biliary Calculus, *Ann. d. Inst. Mod. de clin. med.* **3** 225, 1919.

27 Rothschild, M. A., and Rosenthal, N. Dietetic Management of Hypercholesterinemia, *Am. J. M. Sc.* **152** 394, 1916.

have had, however, a normal blood cholesterol content. These, they infer, undoubtedly had a previous hypercholesterinemia, but the precipitation of the cholesterol under infection and gallstone formation automatically reduced the blood cholesterol content to normal. They divided cholelithiasis into two groups, those with a normal cholesterol content and those with a hypercholesterinemia. The latter consisted of two groups. The first was the obstructive type due to stone, stricture and new growth. In these the cholesterol content became normal on removal of the obstruction. The second group was due to a definite diathesis in which the hypercholesterinemia remained permanent even after the removal of the obstruction, if any was present. This condition they considered an entity as definite as the gouty diathesis. Gallstones were merely one of the evidences of this condition.

In a very recent paper Rothschild and Felson²⁸ noted that in obstructive icterus due to stone, there was a very high hypercholesterinemia bearing a definite relation to the severity of the icterus. In conditions associated with hepatic lesions, however, the cholesterol content was usually normal or below normal, being entirely out of proportion to the icterus. They suggest that in the hepatic disease there is a selective retention of the bile pigment and as a consequence the cholesterol is not retained. This should furnish a means of differentiating icterus of gallbladder origin from that of liver origin. They suggest also that, in operative procedures, the bile passages should be drained long enough to have the cholesterol content of the blood return to normal.

In this series no attempt was made to study intensively the bacterial findings. In 397 cases a history of previous typhoid fever was obtained from only forty patients, or 9.5 per cent. The symptoms of gallbladder disease in these cases dated from six months to forty-nine years after typhoid infection. In those cases of simple cholelithiasis which were subjected to culture, the bile as a rule was sterile, while in the cases of acute cholecystitis and empyema of the gallbladder the organisms found were colon bacilli, streptococcus and staphylococcus. Cushing,²⁹ in his series of gallbladder cases at Johns Hopkins Hospital, reported 30 per cent of cases giving a definite history of typhoid fever. Lichty and Zurhorst,³⁰ in 122 cases of cholelithiasis and fifty-four cases of cholecystitis, found 17.2 per cent and 37 per cent, respectively, giving histories of previous typhoid infection. Rhodes, in 132 cases, reported that 49 per cent of the men and 24 per cent of the women

28 Rothschild, M. A., and Felson. The Cholesterol Content of the Blood in Various Hepatic Conditions, *Arch Int Med* **24** 520, 1919.

29 Cushing, Harvey. Typhoidal Cholecystitis and Cholelithiasis, *Bull Johns Hopkins Hosp* **9** 91, 1898.

30 Lichty, A., and Zurhorst, E. W. Concerning End-Results of Gallbladder and Duct Disease, *J A M A* **65** 482, (Aug 7) 1915.

JACOBSON—GALLBLADDER DISEASE

gave definite histories of previous typhoid fever. In extremes there are a large number of contributors giving percentages. On the other hand, cholecystitis does not appear as a common complication of typhoid fever. Lothrop³¹ reported of 2,864 typhoid cases with only eighteen cholecystitis or 0.6 per cent, and another series of 895 cases in which none were so complicated. In 2,000 cases of simple typhoid fever, to necropsy in Munich, only five, or 0.2 per cent, showed cholecystitis. There evidently is now a marked discrepancy in the gradually decreasing incidence of typhoid fever and the increasing incidence of gallbladder disease, so that the typhoid bacillus may now be considered as the more probable etiologic factor. It has also been reported found in the gallbladder and on the surface of calculi from thirty to forty years after typhoid infection. Persons who reside under such conditions most probably would not be able to recognize the inherent properties of the organism so as to render it recognizable by the ordinary routine culture. Rosenow, with his special technic, has been able to find a higher percentage of cultures than has ever been reported before. That streptococcus and the colon bacillus are the most common organisms. The body, through its many atria of infection, is constantly being infected with organisms, and some of these under favorable conditions, pass by the barriers of resistance, find suitable conditions to grow and produce their disease. The streptococcus, the most prevalent organism of infection, is probably the cause of the greater number of cholecystitis or gallbladder infections.

CLINICAL GROUPS

Patients presenting themselves to the clinic were divided according to symptomatology into the following groups:

Group 1. Typical biliary group. These gave a history of colic evidently associated with the movement of the stool through the biliary passages. The cases were characterized by severe pain localized in the epigastrium or right hypochondrium, sometimes in cessation, radiating usually to the back and shoulder, and accompanied by nausea and vomiting, most of them requiring morphine for relief. Recurrent attacks usually extended over a period of time, were of increasing frequency and were associated with transient jaundice. There were seven cases in which the pain was all left-sided. This group of cases furnished as a rule a correct diagnosis, and consisted of 195 cases or 54.6 per cent.

Group 2 Atypical biliary group In this group there was no acute biliary colic The symptoms were mainly dull aching pain in the upper right quadrant, with tenderness, fever, some nausea and vomiting The pain was usually of several days' duration Jaundice may or may not have been present These attacks were in the main fairly typically inflammatory in character and in findings, were usually accompanied by a septic temperature curve and a fairly high white blood count Gastric symptoms were not marked The cases of intermittent jaundice suggestive of ball valve disease were also included in this group, which included sixty cases, or 16.8 per cent of the total number

Group 3 Gastric Group This group comprised those giving mainly gastric symptoms The attacks were characterized by epigastric distress or discomfort, a feeling of fulness after meals, relieved by belching of gas and sometimes by vomiting Idiosyncrasies for various kinds of foods were quite prominent, giving the so-called "qualitative" food dyspepsia in contrast to the "quantitative" food dyspepsia of gastric ulcer Many of these patients had been treated for years for gastric or duodenal ulcer without any special permanent relief These cases required rather intensive study of the gastro-intestinal tract before a definite diagnosis was made The gastric examinations were fairly negative Forty-nine cases, or 13.7 per cent of the total number, were included in this group

Group 4 Biliary-Gastric Group This group gave symptoms typical of Group 1 and Group 3, namely, that of biliary colic with recurring intervals of gastric symptoms In some, the symptoms of colic were most prominent, in others the gastric symptoms Fifty-three cases, or 14.8 per cent of the total number, made up this group

GASTRIC ANALYSIS

No special assistance in diagnosis was obtained from the analysis of the gastric contents in this series of cases Lichty,³² in 1911, and Lichty and Zurhorst,³⁰ in 1915, reported a hyperchlorhydria in from 50 to 73 per cent of cholelithiasis and cholecystitis cases The former, by experimentation in the dog, had demonstrated an apparent increase in the hydrochloric acid content of the gastric secretion after experimental cholecystitis and cholelithiasis Hohlweg,³³ on the other hand,

32 Lichty, J. A. Relation of Diseases of Gallbladder and Biliary Ducts to the Gastric Secretions, *Am J M Sc* **141** 72, 1911

33 Hohlweg, H. Disturbance in Hydrochloric Acid Secretion in Diseases of and Following Extirpation of Gallbladder *Am J M Sc* **146** 292, 1913, Ueber Störungen der Salzäureabscheidung des Magens bei Erkrankungen und nach Extirpation der Gallenblase, *Deutsch Arch f klin Med* **108** 255, 1912

found a definite acid deficit or a hypo-acidity in cholelithiasis and particularly after removal of the gallbladder or on closure of the cystic duct. Bile itself seems to have no influence whatever on the gastric secretions, as is demonstrated by the experimental cholecystogastroenterostomy of Grey³⁴. Regurgitation of duodenal contents with the bile, of course, lowers the acidity of the gastric contents through addition of the alkaline duodenal fluid. In this series of gallbladder cases, fractional analyses of the gastric secretion were made in seventy-five cases, 82.7 per cent of these were within the limits of normal acidity, 13.3 per cent showed hypo-acidity or anacidity, while only 4 per cent showed a hyperacidity. No special difference was found in the cholelithiasis cases in contrast to the cholecystitis cases.

Meltzer,³⁵ in 1917, observed that duodenal instillation of magnesium sulphate was followed by relaxation of the sphincter of Oddi and a contraction of the gallbladder, there being a general outpouring of bile into the duodenum. Lyons,³⁶ in 1919, made a clinical application of this fact and by a duodenal tube was able to obtain fractional samples of bile representing that from (1) the common duct, (2) stored-up bile from the gallbladder and (3) that secreted by the liver itself. This undoubtedly opens up a new avenue of investigation concerning the bile and its secretion.

ROENTGENOLOGIC DIAGNOSES

Regarding the usefulness of the roentgenologic diagnosis in gallbladder disease there seems to be a diversity of opinion. Various roentgenologists using practically the same technic report positive findings of calculi in from 5 to 90 per cent of cases. The difficulty, of course, is due to the lack of shadow cast by the cholesterol salt calculus. George and Cole³⁷ have perfected their technic so that now they believe all stones should be shown in the roentgenograms. The former³⁸ reports a series of fifty-four cases with only 10 per cent of error in the positive findings, and 6 per cent of error for the whole series. The majority of roentgenologists, however, have not been so

34 Grey, E. S. An Experimental Study of the Effect of Cholecystogastrostomy on Gastric Acidity, *J. Exper. Med.* **23** 15, 1916.

35 Meltzer, S. J. The Disturbance of the Law of Contrary Innervation as a Pathogenic Factor in the Diseases of the Bile Ducts and Gall Bladder. *Am. J. M. Sc.* **153** 469, 1917.

36 Lyons, B. B. V. Diagnosis and Treatment of Diseases of the Gallbladder and Biliary Tract, *J. A. M. A.* **73** 980 (Sept. 27) 1919.

37. George, A. W., and Cole, L. G. The Roentgen Diagnosis of Gallstones by Improved Means, *Boston M. & S. J.* **172** 326, 1915.

38 George, A. W. Some Further Notes on the Roentgen Diagnosis of Gallstones. *Interstate M. J., Suppl. Roentg.* **2** 13 1916.

fortunate thus far in attaining such efficiency. Speed, small focal areas, the taking of many plates and the superposition of plates have helped to increase the efficiency of roentgen-ray diagnosis in gallbladder diseases.

Mayo says that to put too much dependence on the roentgenologic diagnosis of gallstones would be a backward step of many years. Deaver considers it dangerous, first, because it fails to show the stone in the largest number of cases and, second, because it emphasizes the calculus feature. He considers the gallstones as only one of the terminal stages and by no means a uniform accompaniment or the most dangerous feature of the condition. In the series reported here, a positive diagnosis of gallstones was made by roentgen ray in forty-four out of 160 cases, or 27.5 per cent, the findings being confirmed by operation.

OPERATIVE PROCEDURES

Table 3 gives the operative procedure and operative findings of these 397 cases.

COMMON DUCT COMPLICATIONS

Oddi,³⁹ in 1887, discovered a sphincter of plain muscle surrounding the duodenal end of the common duct at the ampulla of Vater. It was composed of circular muscle fibers and could be put into spasm by irritation, mechanical or chemical, from the duodenal side. It was able to withstand an interductal pressure of 675 mm of water. Sphincter action caused an intermittent flow into the duodenum of the bile continuously secreted by the liver and served to maintain a definite pressure in the hepatic duct system. Oddi also observed the dilatation of the extrahepatic ducts in dogs following removal of gallbladder. Archibald,⁴⁰ in 1912-1913, verified the action of the sphincter in maintaining an interductal pressure and showed that incision of the sphincter caused a reduction of the high interductal pressure from 650 to 70 mm of water. This low pressure was maintained for a long time if not permanently. He also proved that pancreatitis could be produced by flooding the pancreas with bile and other substances through the common duct maintained at a pressure above the normal pressure allowed by sphincter action, and suggested cutting the sphincter as one of the surgical procedures in the treatment of this condition. Judd and

39 Oddi, R. Di una speciale disposizione di sfintere allo sbocco del coledoco, Perugia, 1887, quoted by Luciani, L. *Human Physiology* 2:214, 1913.

40 Archibald, E. A New Factor in the Causation of Pancreatitis, *Tr. Int. Cong. Med., Surg. Sect.* 7:21, Part 2, 1913, The Experimental Production of Pancreatitis in Animals as the Result of the Resistance of the Common Duct Sphincter, *Surg., Gynec. & Obst.* 38:529 (June) 1919.

Mann,⁴¹ by extirpation of the gallbladder in dogs, demonstrated the great dilatation of the extrahepatic ducts. Following the operation, the sphincter was evidently in a condition of contraction attempting to maintain the normal interductal pressure. The ducts as a consequence dilate and the sphincter under the continued pressure tension becomes paralyzed with final reduction of the interductal pressure. Eisendrath⁴² and Haberer⁴³ report cases in which they found dilatation of the extrahepatic ducts after cholecystectomy and also cases

TABLE 3—OPERATIVE RESULTS IN CASES OF GALLBLADDER DISEASE

		Chole- cystos- tomy	Chole- cystos- tomy, Chole- dochos- tomy	Chole- cystec- tomy	Chole- cystec- tomy, Chole- dochos- tomy	Chole- dochos- tomy	Chole- cyst enter- ostomy	Repair of Bile Ducts	Explor- atory Lapar- otomy
Cholecystitis									
A Calculous	(315)								
1 Acute		6	1	16	10	1		1	
2 Subacute		0	0	16	6	0			
3 Gangrenous		1	0	10	0	0			
4 Empyema		0	0	7	1	0			
5 Chronic		8	2	134	90	6		2	
B Noncalculous	(50)								
1 Acute		0	0	3	0	1			
2 Subacute		0	0	0	0	0			
3 Gangrenous		0	0	2	0	0			
4 Empyema		0	0	2	0	0			
5 Chronic		1	1	10	5	0			
6 Normal		0	0	16	0	0			
Pancreatitis	(14)								
Acute	(7)								
1 With acute cholecystitis		3	1						
2 With chronic cholecystitis		3							
Chronic	(7)								
1 With acute cholecystitis					1				
2 With chronic cholecystitis		1			5				
Cholelithiasis									
Calculus in									
1 Gallbladder	(244)	20	1	184	39				
2 Common duct	(11)		3			8			
3 Gallbladder and common duct	(78)		4		74				
4 Cystic duct	(7)			7					
Neoplasms									
Carcinoma	(18)								
1 Gallbladder	(6)					1			5
2 Bile ducts	(1)					1			
3 Head of pancreas	(11)	2					5		4

in which a gallbladder-like structure was formed out of the incompletely removed cystic duct. Deaver,⁴⁴ however, in his 1,800 cases of

41 Judd, E. S., and Mann, F. C. The Effect of Removal of the Gallbladder. An Experimental Study, *Surg., Gynec. & Obst.* **24** 437, 1917.

42 Eisendrath, D. N., and Dunlavy, H. C. The Fate of the Cystic Duct after Cholecystectomy, An Experimental Study, *Surg., Gynec. & Obst.* **26** 110, 1918.

43 Haberer and Clairmont. Experimentelle Untersuchungen über das Verhalten des Cysticusstumpfes nach Cholecystectomie, *Arch. f. klin. Chir.* **73** 679, 1904.

44 Deaver, J. B. Cholecystostomy vs Cholecystectomy, *Surg., Gynec. & Obst.* **24** 284, 1917.

gallbladder operations, has not found a single case in which there was any marked dilatation of the ducts following cholecystectomy. From the experimental side, it seems probable that a dilatation of the ducts may follow a cholecystectomy.

Just what constitutes a dilated common duct, in view of the many abnormalities of the gallbladder and biliary passages, it is difficult to say. In the 397 cases reported here, the common duct, in 113 cases, was of such size as to indicate, in the operator's opinion, exploration. In seventy-six cases stone was found in the common or hepatic duct, and no stone in thirty-seven cases. There were also four cases in which the common duct appeared to be normal in size but which contained small stones. In this series a small contracted gallbladder, usually a "nubbin" of a gallbladder, contracted on stones, was found sixty-one times. This gallbladder, usually a mass of fibrous tissue, hard and firm, without any definite lumen, is certainly a nonfunctioning gallbladder and has been produced by a long series of inflammatory insults with or without stone formation. So far as function is concerned, it represents a slow cholecystectomy or progressive obliteration of the gallbladder. With this small contracted functionless gallbladder there was associated a large dilated common duct in thirty-seven cases. Twenty-five of these had stones in the common duct which could no doubt account for the dilatation. In twelve cases there was a large dilated common duct but no stones. On the other hand, however, a small contracted gallbladder was found in conjunction with a small normal common duct twenty-four times.

TABLE 4—COMMON DUCT FINDINGS

	Number of Cases
Small, contracted, fibrous gallbladder	61
A Large dilated common duct	37
(a) With stone	25
(b) Without stone	12
B Small normal, common duct	24

Under normal conditions the gallbladder undoubtedly readily compensates for the usual fluctuations of interductal pressure. After cholecystectomy the tension, if any, is suddenly put on the ducts, and they dilate in the least resistant portion—at or above the junction of the hepatic and common ducts. In slow obliteration of the gallbladder, as is seen in chronic cholecystitis with fibrosis, the ducts slowly accommodate themselves to the gradual increase in the duct pressure by hypertrophy of the walls, by adhesions and by increase in fibrous tissue. In these latter cases also the intrahepatic dilatation is likely to be more pronounced than that occurring after cholecystectomy.

GANGRENE AND EMPYEMA

Gangrene of the gallbladder is a fairly frequent occurrence. It is usually associated with stone impacted in the cystic duct or in a contracted gallbladder. The stone, as the fecolith in acute appendicitis, forms a pressure ulcer, eroding easily its way through the thickened edematous gallbladder wall, devascularized usually by the mechanical obstruction to the blood supply produced by the calculus. Such gangrene associated with stone occurred in this series ten times, or in 2.5 per cent of cases. Gangrene without calculus is rather rare. Kocher,⁴⁵ Korte,⁴⁶ Brunning⁴⁷ and Ransohoff⁴⁸ report cases in detail which on operation showed gangrene of the gallbladder without stone. The gallbladder itself is fairly resistant to gangrenous degeneration, having great powers of recuperation, and most of these patients were operated on from the eighth to the twelfth day. These were undoubtedly due to some severe virulent infection which caused inflammatory obstruction of the cystic duct with secondary interference of the blood supply. Ransohoff suggests that the S-shaped course of the cystic duct may account for the latter feature. With increasing distention, there would be sharper angulation of the cystic duct with its accompanying cystic artery, causing more complete obstruction not only to the cystic duct, but to the artery itself. Gangrene of the gallbladder without stones occurred in this series in two cases. Empyema, in a similar way, is usually caused by obstruction to the cystic duct, either by a stone impacted there or in the ampulla of the gallbladder, forming first a hydrops and then, by infection, an empyema. Such a condition occurred in thirteen cases in this series. Two of these empyemas were unassociated with calculus and were entirely inflammatory.

PERFORATION OF THE GALLBLADDER

Perforation of the gallbladder was found in six cases. Three of these were perforations into the duodenum without any acute peritoneal symptoms when admitted. On operation, they showed the usual mass of hard, fibrous tissue between the gallbladder and duodenum, suggestive of a gallbladder duodenal fistula. One was of more recent formation and was accompanied by a large colon bacillus abscess, subhepatic on the posterior abdominal wall. In all these cases

45 Kocher, Theodor. Ueber 100 Operationen an den Gallenwegen mit Berücksichtigung der Dauererfolge. *Arch f klin Chir* 81: 655, 1906.

46 Korte. Weitere Erfahrungen über Operationen an den Gallenwegen. *Arch f klin Chir* 89: 1, 1909.

47 Brunning. Cholecystitis acutissima haemorrhagica. *Deutsch Ztschr f Chir* 103: 407, 1909.

48 Ransohoff, J. L. Acute Gangrene of Gallbladder Following Injury. *Ann Surg* 62: 420, 1915.

the fistula into the duodenum was closed and cholecystectomy was performed. There was one case of multiple perforations of a huge gangrenous gallbladder with general peritonitis, a terminal condition, the patient succumbing in two hours after abdominal drainage.

NORMAL GALLBLADDER

A normal gallbladder was removed in sixteen cases. This diagnosis was made on the microscopic examination, considering round cell infiltration, the presence of inflammatory cells as eosinophils and some increase in the fibrous tissue of the walls as indicative of a diseased gallbladder. These sixteen cases were unassociated with calculus. They must be considered definitely as wrong diagnoses. They were for the most part patients with vague gastric symptoms, with suggestive gallbladder findings on roentgen-ray examination. Error in diagnosis is also substantiated by the follow-up record of these cases, five out of seven patients reporting themselves as unimproved or in worse condition than before operation.

RECURRENCES AND SECONDARY OPERATIONS

Recurrences following gallbladder operation and requiring secondary surgical interference are fairly frequent, depending largely on the operator and the variety of the lesion. Judd,⁴⁹ of the Mayo Clinic, in 1918, reported 219 cases out of a total of 2,027, or 10.8 per cent. Sixty-four of these cases had the primary and secondary operation at that clinic. Deaver,⁴⁴ reporting 1,189 cases, had fifty-one secondary operations, or 4.2 per cent, 60 per cent of these coming to operation in the first year, 90 per cent within three years, and the remainder from four to seventeen years after the primary operation. Stanton⁵⁰ reporting the experience of six operators with a total of 1,173 cases, found recurrences in from 2 to 10 per cent of cases treated by the various operators. Recurrences are classified as true or false, the former including those of evident reformation of calculus in the gallbladder and bile ducts. Naturally, they are found mainly in those cases in which a primary cholecystostomy was performed. The false recurrences include (1) stones overlooked at the first operation, (2) a persistence of the primary infection, (3) adhesions incidental to operation and (4) chronic pancreatitis. The work of Aschoff and Bacmeister,²¹ confirmed by Ehrhardt,⁵¹ has shown calculi reforming in

49 Judd, E. S. The Recurrence of Symptoms Following Operation on the Biliary Tract, *Ann Surg* 67 472, 1918.

50 Stanton, E. Reformation of Gallstones after Operation, *Ann Surg* 61 226, 1915.

51 Ehrhardt. Beiträge zur pathologischen Anatomie und Klinik des Gallensteinleidens, *Arch f klin Chir* 83 1118, 1907.

the depths of Luschka's crypts or glands, which have been extruded to serve as the focus for reformation of stones. With the infected gallbladder remaining, stones may and will be found to recur after cholecystostomy. There seems to be no doubt that calculi can increase greatly in size while in the extrahepatic ducts, and cases have been reported in the literature of evident formation of calculi in the common duct, but it is extremely difficult to rule out the probability of stones overlooked at the previous operation. It seems rather strange that surgical reports do not contain more evidence of the intrahepatic formation of calculi, as such conditions have been found fairly frequently in postmortems. Beer,⁵² in 1904, dissected 250 livers of patients who succumbed to gallbladder disease and found six cases of definite intrahepatic stone formation, or in 2.5 per cent. Lewisohn,⁵³ in 1916, reported a case of intrahepatic stone formation, there being several stones in the liver passages and one rupturing through the surface of the liver, forming a peritonitis. Hawkes⁵⁴ had previously reported a similar case, and Lenhartz,⁵⁵ in 1903, described a case in which the large and small intrahepatic ducts were filled with many calculi in various stages of formation, while the gallbladder was entirely devoid of the same. These appear to be the only cases of intrahepatic calculi in surgical literature. The stones seemed to be of different form, structure and character than those formed in the gallbladder, and according to the previously named authors are fairly well recognized. By far, however, the greatest number of occurrences are due to overlooked stones. Kehr,⁵⁶ in reporting 1,105 cases between the years 1890 and 1909, admitted overlooking calculi in 2.5 per cent of cases. McWilliam⁵⁷ reported seven in sixty-nine cases at the Presbyterian Hospital in New York, and Whittemore⁵⁸ reported thirty secondary operations for similar cause in 325 cholecystectomies in the Massachusetts General Hospital. Kehr⁵⁹ explored forty-six common ducts in

52 Beer, E. Intrahepatische Cholelithiasis, *Arch f klin Chir* **74** 115, 1904

53 Lewisohn, R. Intrahepatic Cholelithiasis, *Ann Surg* **63** 535, 1916

54 Hawkes, F. A Case of Intrahepatic Calculi, Removal, Drainage, *Rep Presbyterian Hosp* **7** 230, 1906

55 Lenhartz, Hermann. Die septischen Erkrankungen, *Nothnagel's Handbuch (Spezielle Pathologie und Therapie)*, 1903, p. 363

56 Kehr, H. Wie können wir Residive nach Gallensteinoperationen vermeiden und einschränken? *München med Wchnschr* **58** 2425, 1911

57 MacWilliam, C. A. Critical Analysis of 186 Operations on the Liver and Gall Passages and the After-Results, *New York M J* **83** 1109, 1175, 1238, 1906

58 Whittemore, W. Surgery of the Biliary Passages During a Period of Ten Years, June, 1901, to June, 1911, at Massachusetts General Hospital, *Boston M & S J* **169** 571, 1913

59 Kehr, H. Wann soll man nach einer Ektomie bei negativem Palpationsbefund von Steinen im Choledochus diesen Gang incidieren und drainieren und wann nicht? *Arch f klin Chir* **97** 301, 1912

which palpation was entirely negative, and found calculi in seventeen cases in the retroduodenal portion of the common duct Eisendrath,⁶⁰ in a similar way, found ten cases of calculi in the common duct in thirty cases in which external evidence and palpation failed to demonstrate the presence of the stone. Palpation of the supraduodenal portion of the common duct is fairly readily accomplished, but stones in the stagnant bile in the retroduodenal portion of the common duct just above the ampulla of Vater are very easily overlooked.

TABLE 5—RECURRENCES AND SECONDARY OPERATIONS

Secondary Operation	Cases
A Cholecystostomy for common duct stone	8
Primary Operation	
Cholecystectomy for stone	2 cases
Cholecystostomy for stone	1 case
Cholecystectomy, Cholecystostomy for stone	5 cases
B Cholecystectomy for stone	6
Cholecystostomy for stone	6 cases
C Cholecystectomy, cholecystitis no stone	6
Cholecystostomy for stone	6 cases
D Cholecystectomy, cholecystostomy for stone	6
Cholecystostomy for stone	6 cases
E Exploratory laparotomy for malignancy	2
Cholecystectomy for supposed chronic cholecystitis and pancreatitis	2 cases
F Repair of injured bile ducts	2
Among these 80 cases requiring secondary operations there were 16 which had the primary and secondary operations in this hospital	
A Primary cholecystostomy for stones in the gallbladder	6
B Injury to bile ducts requiring secondary operation (1 fatality)	3
C Secondary laparotomy for malignancy of biliary tract, primary operation being for chronic cholecystitis and pancreatitis error in diagnosis	2
D Cases of definitely overlooked stone in bile ducts	5
Primary Operation	Secondary Operation
1 Cholecystectomy	Cholecystostomy
2 Cholecystectomy	Cholecystostomy
cholecystostomy	Cholecystostomy
3 Cholecystectomy	Cholecystostomy
4 Cholecystostomy	Cholecystectomy
	cholecystostomy
5 Cholecystectomy	Cholecystostomy
cholecystostomy	Cholecystostomy (fatality)

In this series of 397 cases, confirmed by operation, there were thirty cases of recurrences or persistence of symptoms requiring secondary operation, a total series percentage of 7.5. Of these thirty cases, in sixteen cases the primary and secondary operations were performed in this clinic. This gives a percentage of 4.2 for secondary operation for the hospital series. This is a fairly low percentage and is due most probably to the fact that except for the earlier cases—accounting for six recurrences—cholecystectomy has been the operation of choice whenever feasible. Lund⁶¹ quotes from statistics of a number of experienced operators, such as Mayo, Finney, and others, a symptomatic cure following cholecystostomy in about 75

60 Eisendrath, D. N. Recurrences after Operations on Biliary Passages, *J. A. M. A.* 69:1752 (Nov. 24) 1919.

61 Lund, F. B. The Indications for Cholecystectomy, *Surg., Gynec. & Obst.* 24:275, 1917.

per cent of cases, 25 per cent of patients operated on having somewhat similar symptoms. Out of twenty-six recurrences directly associated with cholelithiasis and cholecystitis, twenty had stones removed at the second operation, stones evidently having reformed or having been overlooked at the first operation, six were cases of cholecystitis without stones. Of the sixteen recurrent cases from this clinic, six were recurrences from former cholecystostomy, three of which had stones and three of which were cholecystitis. There were two cases which evidently were due to error in diagnosis, chronic pancreatitis being diagnosed at the primary operation and malignancy of the pancreas at the second. Three secondary operations were for injury to the bile ducts, and five were for definitely overlooked stones. It is regrettable that one of the patients with injury to bile ducts and one with overlooked stone succumbed after the secondary operation.

This does not include nine cases in which there had been previous operations for similar symptoms with no relief, evidently mistaken diagnosis. These comprise eight cases of appendectomy without relief of symptoms and one exploratory laparotomy with negative findings. These operations were all performed in other clinics. These nine patients had rather vague symptoms, mainly of gastric or duodenal character and gave some suggestive evidence, on roentgen-ray examination, of gallstone disease. In seven of the nine cases there was found definite cholecystitis or cholelithiasis or gastric or duodenal ulcers, in two there was a normal gallbladder.

INJURY TO BILIARY DUCTS

There are recorded in this series five cases of operative injury to the common duct, all of which occurred in this clinic. Two of these were repaired at the primary operation and three required secondary operation. These were in reality surgical errors due (1) to the difficulty of recognizing landmarks on account of the large mass of fibrous adhesions surrounding the ducts, and (2) failure to recognize some of the abnormalities of the biliary ducts and blood vessels which occur so frequently and have been noted in detail by Eisendrath⁶². Two of these divided common ducts were resutured and three were repaired over a rubber tube, one of which was removed at a secondary operation. The other two retained their tubes in the common ducts as shown by the roentgen-ray sixteen and twelve months after the operation. These patients are perfectly well and have no discomfort whatever. One of these five patients with injury to the common duct succumbed after the second operation.

⁶² Eisendrath D. N. *Anomalies of the Bile Ducts and Blood Vessels*. J. A. M. A. 71:864 (Sept. 14) 1918.

PANCREATITIS

There undoubtedly is in the majority of cases a close association between primary infective diseases of the gallbladder and a complicating pancreatitis. Among the several etiologic factors of the latter disease there have been mentioned the retrojection of bile into the pancreas by obstruction at the ampulla of Vater and the extension of biliary sepsis either as an ascending infection to the pancreas or by way of the retroperitoneal lymphatics. Linder⁶³ found 50 per cent of pancreatitis cases depending on or subsequent to cholecystitis and cholelithiasis. May reports that 85 per cent of all pancreatitis cases are associated with gallstones and that 25 per cent of them have common duct stones. He also remarks that 7 per cent of all cases with gallstones in the gallbladder are associated with pancreatitis in some form, indicating that pancreatitis is four times as frequent with common duct stone.

In the series reported in this paper, acute and chronic pancreatitis was encountered fourteen times, as may be seen in Table 6.

TABLE 6—OCCURRENCE OF ACUTE AND OF CHRONIC PANCREATITIS

		No. of Cases
Acute Pancreatitis		
(a) Hemorrhagic type	This is the fulminating type with hemorrhagic blood clot pancreas, blood stained abdominal fluid, fat necrosis, extreme toxemia	5
	Associated with acute cholecystitis	8 cases
	Associated with chronic cholecystitis	2 cases
	Calculus in all cases—	
	Common duct obstruction stone in ampulla	1 case
	Common duct obstruction, swollen pancreas	1 case
(b) Acute gangrenous pancreatitis, partial destruction of head of pancreas with abscess formation, fat necroses		3
	Associated with acute cholecystitis	3 cases
	Calculus in all cases—	
	Common duct obstruction stone in ampulla	1 case
	Abscess in head of pancreas	2 cases
(c) Subacute pancreatitis, swollen soft pancreas, frequent fat necroses associated with acute cholecystitis		2
Chronic Pancreatitis		
	This is the large, hard firm, indurated pancreas suggestive of malignancy on palpation, often times producing obstruction to the lower portion of the common duct	4
	Associated with acute cholecystitis	1 case
	Associated with chronic cholecystitis	3 cases
	Calculus in gallbladder	4 cases
	Obstruction to common duct by enlarged pancreas	1 case

All of these cases were associated with acute or chronic cholecystitis, usually of long duration, and all gave a history of biliary colic. Calculi were found in all but two of the cases, and there were two cases of definite obstruction at the ampulla of Vater by stone. In the acute cases of hemorrhagic type the patients were extremely ill, all of them succumbing in several hours after admission, two of them were practically moribund and did not survive attempted laparotomy. Drainage

63 Linder, William. Diagnosis of Acute Pancreatitis, J. A. M. A. 69:718 (Sept. 1) 1917.

of the pancreas was the primary operation, with accessory drainage of the gallbladder if the patient's condition allowed. All of the patients with chronic pancreatitis did well. Cholecystectomy and choledochostomy with long continued drainage of the common duct was the operation of choice.

NEOPLASMS

Neoplasms of the gallbladder and biliary passages occurred in eighteen cases, or 4.5 per cent of cases. Nine of these were entirely inoperable, nothing further being attempted beyond the exploratory laparotomy. Five cases were relieved by a cholecystenterostomy. Carcinoma of the gallbladder itself was encountered six times, five of them allowing of no operation on the gallbladder and one permitting a palliative choledochostomy. Carcinoma of the bile passages was very rare. In this series there was one case, namely, carcinoma of the hepatic duct above its junction with the common duct. There was complete obstruction, the common duct and gallbladder having no bile but a thick mucous fluid such as found in the ordinary hydrops of the gallbladder. Carcinoma of the head of the pancreas producing biliary obstruction occurred nine times, five of which permitted cholecystenterostomy, with relief for a period of thirteen months in the longest case. Most of these patients were deeply jaundiced, and there was a distressing oozing of blood in three of them following operation. In two, bleeding persisted for about three days and in the other for four days, the latter case ending fatally. As far as preventing persistent oozing, these patients did not react well to administration of blood serum or calcium lactate feeding by mouth. Whipple⁶⁴ has reported excellent results by intravenous infusions of 0.2 per cent calcium lactate solution in amounts of 200 to 500 c.c. When this was given preoperatively to the intensely jaundiced patients there was very little bleeding. If given after the oozing started, the hemorrhage invariably stopped. He considered this treatment far superior in results to either administration of serum or blood transfusion.

CHOLECYSTOSTOMY VERSUS CHOLECYSTECTOMY

In this series of 397 gallbladder operations, cholecystostomy was performed sixteen times in contrast to 225 of cholecystectomy. In general, there has been a gradual decrease in the sphere of usefulness of the former operation. In the earlier cases of this series cholecystostomy was used in this clinic as the operation of choice. Owing however to recurrences both of cholelithiasis and cholecystitis, it has been reserved in this clinic for those acute cases in which the patient's

⁶⁴ Whipple, A. O. History Analysis Applied to Surgical Diseases of the Biliary Tract and the Pancreas, *Ann. Surg.* 68:471, 1918.

condition contraindicated cholecystectomy or those few cases in which the gallbladder is necessary for cholecystenterostomy Deaver⁴⁴ has estimated that 65 per cent of his recurrences could have been obviated by removal of the gallbladder Infection of the gallbladder wall is the essential factor in gallbladder disease with calculus formation as an accessory product of inflammation in about 75 per cent of cases The persistence of this chronic infection, with or without stone formation, is the cause of most of the subsequent recurrences, complications and the lowered percentage of symptomatic cures following cholecystostomy It is also closely associated with the subsequent metabolic degenerative and organic changes in the body which increase the mortality rate in those cases subject to long-standing biliary infection So far as can be ascertained, cholecystectomy has no special detrimental effect on the body economy Patients observed by Mayo postoperatively for fifteen years have shown no special discomfort or disability With the improvement in bacterial technic and with special means of diagnosis one wonders if a gallbladder, once the seat of infection, ever really becomes a normal functioning gallbladder or one free from infection The recurrences following cholecystostomy are usually inflammatory and of a character similar to the primary infection Those following cholecystectomy are usually mechanical and can be obviated by further care in the operative procedure The mortality of the two operations is not essentially different in the simple cases Deaver remarks that the mortality difference is as nothing compared to the local disease and general condition of the patient In this clinic it has been the practice to consider cholecystectomy the operation of choice in all acute and chronic gallbladder infections when not contraindicated by the patient's condition Cholecystostomy has been reserved for the acute critical suppurative cases or where a cholecystenterostomy was demanded

FATALITIES

The deaths in this series numbered twenty-six, including all cases According to operation, they are given in Table 7

The mortality for the whole series of 397 cases was 6.5 per cent Deducting the four terminal cases in which the patient succumbed on attempted laparotomy—moribund cases—gives a mortality of 5.5 per cent, divided as follows

- 1 Acute and chronic gallbladder lesions requiring cholecystectomy—five deaths out of 224 cases, or 2.7 per cent
- 2 Acute and chronic cases with common duct involvement requiring exploration of the common duct—twelve deaths in 126 cases, or 9.5 per cent
- 3 Pancreatitis, acute and chronic, requiring drainage of pancreas, cholecystostomy, cholecystectomy or choledochostomy—five deaths in fourteen cases, or 36 per cent

There is thus seen a gradual increase in the mortality rate with the increasing complication in the disease itself. This strongly argues for the early recognition and early operation in gallbladder disease.

TABLE 7—DEATHS

	Time	Cause
Cholecystectomy		
1 Chronic cholecystitis and cholelithiasis	Sudden 11 hrs	Unknown
2 Chronic cholecystitis and cholelithiasis	40 hours	Postoperative pneumonia
3 Chronic cholecystitis and cholelithiasis	36 hours	Postoperative pneumonia ?
4 Chronic cholecystitis and polyps	Sudden 8 hrs	Cardiac decompensation
5 Chronic cholecystitis and chronic hepatitis	Sudden, 1½ hrs.	Portal stasis
6 Chronic cholecystitis and cholelithiasis	Sudden 12th day	Unknown
Cholecystectomy and Choledochostomy		
1 Chronic cholecystitis and cholelithiasis	3 days	Acute gastric dilatation
2 Chronic cholecystitis and cholelithiasis	4th day	Postoperative pneumonia
3 Acute cholecystitis and cholelithiasis	18th day	Septic cholangitis
4 Chronic cholecystitis and cholelithiasis	2d day	Bronchopneumonia, rupture of wound requiring secondary operation
5 Chronic cholecystitis and cholelithiasis	4th day of pneumonia	Transduodenal exploration of ampulla, peritonitis ?
6 Chronic cholecystitis and cholelithiasis	42 days	Overlooked stone, transduodenal exploration of ampulla, septic course
7 Chronic cholecystitis and cholelithiasis	Sudden 16 hrs	Temperature, pulse and respiration like pneumonia
8 Chronic cholecystitis and cholelithiasis	10th day	Uremia
9 Acute cholecystitis and cholelithiasis	6th day	Uremia
10 Chronic cholecystitis and cholelithiasis	6th day	Uremia (early carcinoma, ducts)
11 Acute pancreatitis	27th day	Uremia septic course
Cholecystostomy		
1 Acute gangrenous perforated gallbladder peritonitis	5-6 hrs after abdominal drainage	Terminal case
Choledochostomy		
1 Septic cholangitis multiple liver abscesses previous cholecystectomy and choledochostomy one year before	3 days	Septic course
2 Overlooked common duct stone, previous cholecystectomy and choledochostomy 5 months before	17th day	Postoperative hemorrhage, rupture of wound as thenia
Drainage of Pancreas and Abdomen		
1 Acute hemorrhagic pancreatitis	6 hours	
2 Acute hemorrhagic pancreatitis, gangrenous gallbladder	13th day	Septic course
3 Acute hemorrhagic pancreatitis	30 hours	
Attempted Laparotomy		
1 Acute hemorrhagic pancreatitis		Terminal case
2 Acute hemorrhagic pancreatitis		Terminal case

Of the twenty-six fatalities, there were seven cases in which the patients were practically moribund on admission or so overwhelmed with sepsis that they succumbed either during operation or a few hours afterwards. It is questionable whether attempted operation in some of these cases was justifiable. Excluding those cases in which sepsis was the predominant feature, the most frequent postoperative complications leading to death were postoperative pneumonia and uremia. There were six cases with fatal outcome in which pneumonia—a postoperative pneumonia—seemed to be the causal factor. Ether was used in most of these cases and the anesthesia proceeded smoothly throughout the cases in question. Postoperative pulmonary complications, both minor and major, have not as a rule been more

frequent in gallbladder operations than in other operations on the upper abdomen in this clinic. There is required, however, a little deeper anesthesia for relaxation, and working under the diaphragm may cause some pulmonary embarrassment. The resulting pneumonia is undoubtedly due not only to ether, but to a combination of causes such as trauma, operative shock, preoperative pulmonary irritability, sepsis and irritation from ether inhalation. There were four deaths from uremia with complete suppression of urine following operation. None of these cases showed anything unusual in the urine preoperatively. None of these cases were emergency cases, and the suggestion is made of the advisability of having functional tests on all patients undergoing such operations, with a view to increasing therapeutically the functional capacity of the kidney, preoperatively, if it is found low.

Two hundred and one cases were heard from in response to follow-up letters for final results two to four years after operation. These are given in Table 8.

TABLE 8—FINAL RESULTS

	Operation					
	Chole- cystostomy	Per Cent	Chole- cystectomy	Per Cent	Chole- cystectomy, Chole- dochoostomy	Per Cent
Number of cases	17		125		59	
Well	11	64.7	110	88.0	57	96.6
Improved			9	7.2		
Total well and im- proved	11	64.7	119	95.2	57	96.6
Unimproved	6 (secondary operation)	35.3	6	4.8	2	3.4

In this series there is evidently a larger percentage of cured cases among those with common duct complications requiring cholecystectomy and choledochostomy. This is due (1) to the fact that the error of diagnosis is less in these complicated cases in contrast to the number of normal gallbladders removed in the simpler cases, and (2) to the beneficial effect of long continued drainage of the biliary passages. This seems to confirm Archibald's observation that in the complicated cases of cholecystitis and pancreatitis, long continued drainage of the common duct is followed by the persistence of fewer postoperative symptoms than in the undrained cases.

SUMMARY

1 Gallbladder disease — cholecystitis and cholelithiasis — is a disease of middle age occurring with special frequency in women and closely associated with the increasing incidence of pregnancy.

2 Many cases evidently originate in early age and persist with only vague indefinite symptoms until later in life

3 Gallstones are due in all probability to a hematogenous infection, commonly streptococcal, of the gallbladder and biliary passages and are associated with an altered cholesterol content of the blood

4 Common duct and pancreatic complication are of frequent occurrence in the long persisting cases

5 There appears to be no special dilatation of the extrahepatic biliary passages in the slow obliteration of the gallbladder through chronic infective processes with fibrosis

6 Recurrences are due mainly to overlooked or reformed stones, persistence of the original infection or to its extension as a chronic pancreatitis

7 Injury to the biliary passages during operation is due to the rather frequent abnormalities in the blood vessels and biliary passages

8 Cholecystectomy is the operation of choice in cholecystitis and cholelithiasis whenever feasible. There is a marked beneficial effect in the long continued drainage of the biliary passages in the complicated cases of cholecystitis and pancreatitis

9 There is no special detrimental effect of cholecystectomy on the body economy

10 There is an increasing mortality rate with the increase in the complications of disease. This is an argument for early diagnosis and operation

OPEN PNEUMOTHORAX

AN EXPERIMENTAL STUDY OF THE FUNCTIONAL PATHOLOGY OF SUCKING CHEST WOUNDS

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- IV CLINICAL CORRELATION AND COMMENT
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I INTRODUCTION

Pneumothorax, opening externally in the form of the "sucking" chest wound of warfare, or as the result of operations on the chest, especially for empyema, is of fairly frequent occurrence and of very serious import. I have been unable to find in the literature much serious study of the functional changes which lead to the frequently fatal outcome. Therefore, further observations seemed appropriate. The present report deals with experimental pneumothorax in the rabbit. The features especially considered are the volume of air respired per minute, the respiratory exchange of oxygen and carbon dioxide and their relation, the respiratory quotient, the total carbon dioxide content of the blood, and the acid-base equilibrium of the blood. The changes in the circulation of the blood have not been studied because of the technical difficulties of determining the minute volume of cardiac output.

II METHODS

Rabbits were used throughout the experiments. They were anesthetized with 5 c c of 20 per cent urethane per kilogram, given by rectum. This dosage was varied a little for different lots of rabbits (depending on age, breed, etc), the aim being to secure a light degree of anesthesia, preserving at the same time a responsive respiratory center and active corneal reflexes. Owing to the lightness of the anesthesia, the preliminary operation for the introduction of tracheal and pleural cannulas was carried out under the influence of a few whiffs of ether. The same tracheal and pleural cannulas were used in all of the experiments. The specially devised pleural cannula was of

a slightly greater diameter than the tracheal cannula, so as to allow an easy exchange of air into and out of the pleura. A purse string suture was sewed around a small opening in the muscles between the ribs of the right side and drawn tight as the conically pointed cannula was plunged through the pleura. By means of this procedure the normal pleural pressure was not lost. After periods of pneumothorax a negative pressure could be induced and maintained in the pleura by closing the cannula. A routine negative pressure of 30 cm, indicated by a water manometer, was used during the periods designated as "closed," following the periods of pneumothorax. The first "normal" observations were always taken after the pleural cannula had been inserted, and before it was opened, allowing some time for the animal to become quiet, so as to avoid the effects of the operative hyperpnea. When blood was examined, it was obtained by aspiration through a needle from a previously exposed carotid artery. It may be said that after the necessary operative procedures had been completed the animals remained practically undisturbed. Their condition was further controlled by observing the rectal temperature from time to time. All of the animals used were in good condition. None had been previously starved or placed on special diets.

III RESULTS

1 *Mechanical Changes in Respiration*—When one pleural cavity is opened, the negative inspiratory pressure, as measured by a manometer, is reduced practically to zero. The lung on this side, owing to its elasticity, collapses more or less completely, but probably never entirely. The mediastinum, if sufficiently elastic, is drawn to the sound side, reducing the negative pressure on that side also, except as the animal may be able to compensate for it by increased respiratory effort. This compensation appears to be brought about by the animal's superimposing the respiratory movements on an average position of the chest more or less approaching the position at complete inspiration.

The decrease in the average degree of distention of the two lungs decreases the alveolar surface, and thus tends to encroach on the area through which the gases must diffuse into and out of the blood. In order to maintain or increase the difference between the partial pressure of the gases in the alveoli and in the blood, so as to increase the exchange of gas per unit area of alveolar surface, and thus to maintain a normal total exchange of gases, the alveoli must be hyperventilated. Furthermore, the "dead" space of the trachea and bronchi is increased in proportion to the active alveolar surface. There will be poorer ventilation of the alveoli in pneumothorax than under normal conditions by a tidal air in each case of a magnitude equally propor-

tional to the total volume of both the dead space and the alveoli. The bailing out, as it were, of the alveoli must be increased over the normal if the embarrassment of respiration due to pneumothorax is to be compensated for. The experiments of the next section will show what changes really occur in the volume of air respired per minute during pneumothorax as compared to the normal.

2 *The Minute Volume of Respiration*—Immediately after the pleural cannula is opened, the quietly breathing animal is suddenly seized with an intense dyspnea. The change in the character of the respiratory movements is so marked that the volume of air respired per minute appears to be increased. A part of the increased muscular effort is undoubtedly wasted in moving the air in and out through the pleural cannula, and in attempting to ventilate the partially collapsed lungs which now possess a dead space of trachea and bronchi increased

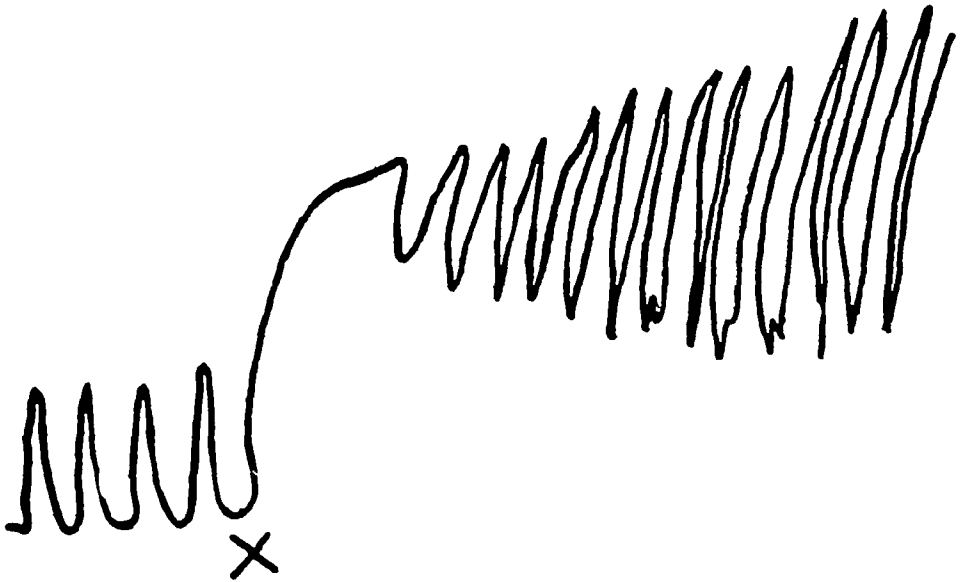


Fig 1—Tracing of contractions of slip of muscle of diaphragm. At X the pleura was opened. There followed an inspiratory tetanus, and then hyperpnea (Taken from Henry Head¹)

out of proportion to the area of active alveoli. The character of this dyspnea is illustrated by the accompanying tracing taken by Henry Head¹ in 1889 (Fig 1). Studying another problem, Head observed the activity of the respiratory muscles, by tracing the movements of a slip of the muscle of the diaphragm. He found that when the pleura was opened there was an immediate inspiratory tetanus, followed shortly by a marked degree of hyperpnea.

We used two methods to study the changes produced in the minute volume of respiration. In Method A, the animal was placed in a

1 Head, Henry. J. Physiol. **10** 279, 1889

large glass jar, with a lid which could be sealed air-tight. The tracheal and pleural cannulas were connected by rubber tubing with the outside. By means of a screw clamp whose shaft passed through the lid, the pleural cannula could be opened or closed without removing the lid of the bottle. The bottle was connected by rubber tubing to a Gad spirometer of small dimensions, carefully balanced and fitted with a light pointer for tracing on a kymograph. By this arrangement, a record of the changes in the volume of respiration was obtained, since on inspiration a volume of air, equal to the volume of air inspired from the outside, would be displaced from the bottle by the increase of the volume of the animal's thorax. On expiration the opposite would occur. In a few experiments the blood pressure was also recorded by a mercury manometer, in the usual manner.

In Method B, light aluminum valves, separating the inspired from the expired air, were attached to the tracheal cannula. The expired air was led to a Gad-Bohr spirometer of larger size than that used in

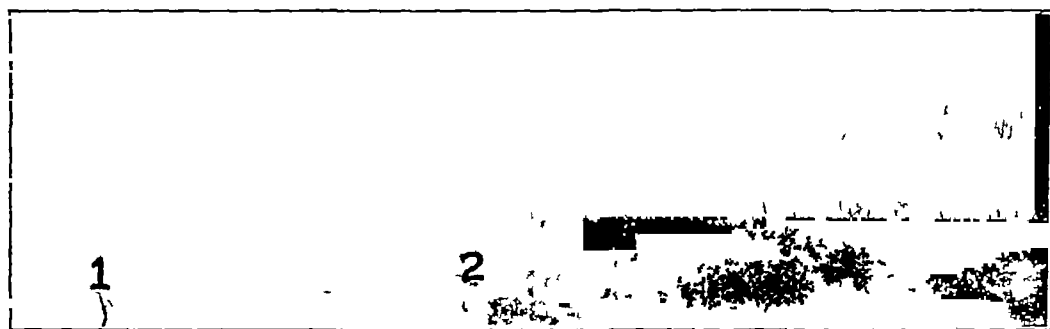


Fig 2—Minute volume of respiration taken by Method A. 1, thorax unopened, 2, pneumothorax produced

Method A. With such an arrangement an obliquely rising line was drawn by the spirometer on the smoked drum. The steepness of this line indicated the minute volume, in some approximate proportion at least.

The results obtained were practically without variation. Both methods showed the minute volume to be decreased during pneumothorax. The results were rendered more certain by alternating periods of opened and closed thorax. The tracings in Figures 2, 3, 4, 5 and 6 are typical of the results obtained in seventeen experiments.

Figure 2 shows the first normal control, followed by the first period of pneumothorax. There was a decrease in the amplitude of respiration, together with a slight increase in rate. Careful calibration showed that the minute volume was decreased. Figure 3 shows four superimposed curves, sections of a tracing taken four times continuously around the kymograph. Reading from below upward,

the thorax was opened, closed, opened, closed. The "closed" tracings here presented were taken subsequent to pneumothorax, and indicate a ventilation greater than normal, in compensation for the conditions supervening during pneumothorax. Figure 4 shows periods of open, closed and opened thorax, with corresponding small, large and small minute volume, and with the blood pressure lower during the closed period.

By Method A, the minute volume was expressed by the product of the amplitude of the curves multiplied by their frequency. Both factors did not always change simultaneously and in the same direction. Therefore it was not always easy to estimate, except by very careful

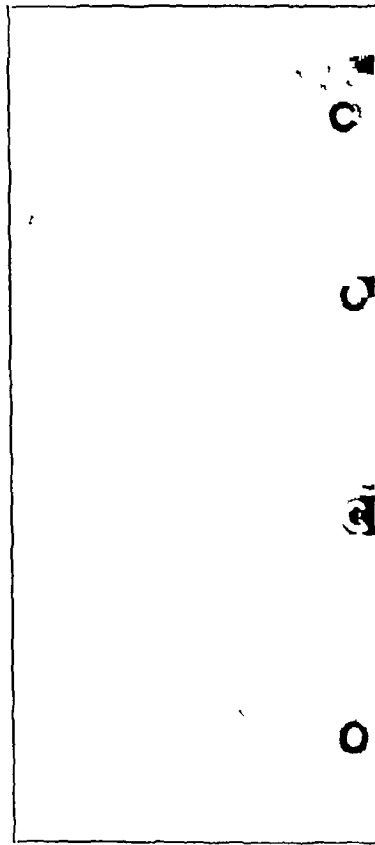


Fig. 3—Minute volume of respiration taken by Method B. O, open thorax, C, closed thorax. Read from below up.

calibration, the minute volume, although there was always a striking change in at least one of the factors. This difficulty was obviated by Method B, as just described. Here the minute volume was expressed directly by the obliquity of the curve. Figure 5 is an example of this. At the left, the uppermost curve represents part of a control (closed thorax). About the middle of the next curve, when the chest was opened, the curve immediately flattened. The next

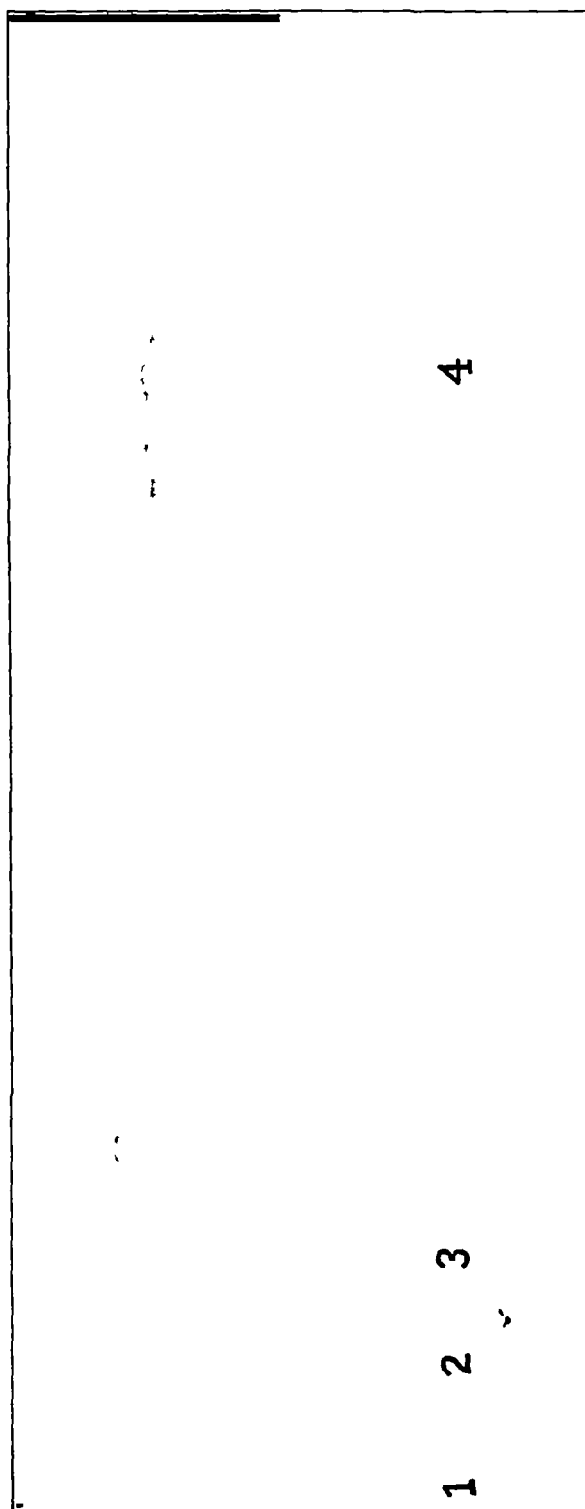


Fig 5—Minute volume of respiration taken by Method B artery, lower curve represents minute volume of respiration 1, part of tracing taken during pneumothorax, 2, pleural cannula closed, 3, negative pressure produced in pleural cavity, and 4, pleural cannula again opened

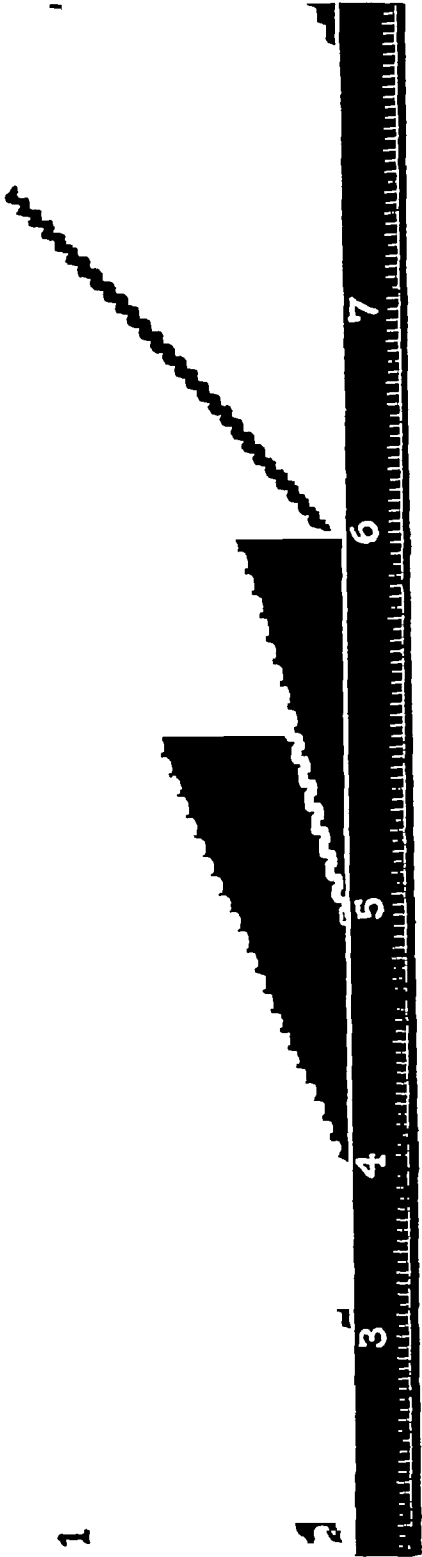


Fig 5—Minute volume of respiration taken by Method B 1, control, 2, control, with pneumothorax produced at middle of curve, 3, 4 and 5, taken during continuation of pneumothorax, 6 and 7, taken after pleural cannula had been closed

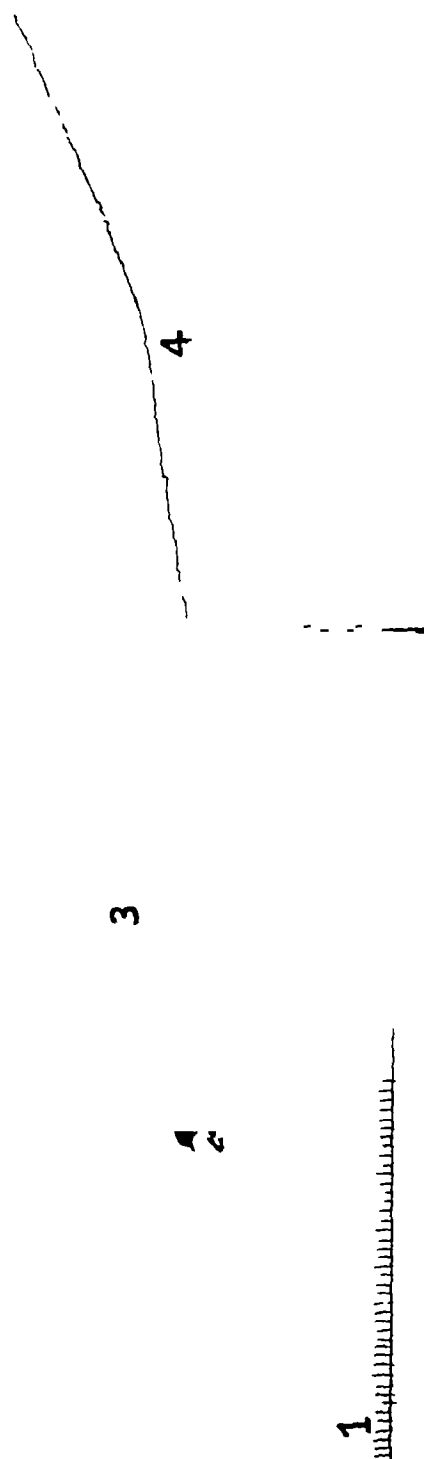


Fig 6—Minute volume by Method B 1, control, 2, pleural cannula opened, 3, large opening cut in the thoracic wall, 4, opening closed with hand at the height of inspiration

three curves are progressively flatter as the animal approached death. The tube in the chest was then closed and the two subsequent curves obtained. These show a much steeper ascent, indicating an approach toward the normal minute volume.

Figure 6 shows a curve which emphasizes the great importance of the dynamic factor of air rushing in and out of the pleural opening, as compared with the relative nonimportance of the static factor of the degree of pulmonary collapse. Starting at the left with a control, the pleural tube was opened and the curve flattened. An opening in the thorax, 5 or 6 cm. in diameter, was then made. The curve flattened a little more. The degree of the collapse of the lung could then be seen. By placing the hand over the opening at the height of the inspiratory phase, so as to develop the least possible negative pressure, and consequently the least possible distention of the lung, the curve immediately became steeper, and gained an obliquity approximating the control curve.

These results being constant, it accordingly seems justifiable to conclude that the rabbit is unable to compensate by means of an increased minute volume for the pathologic changes in the mechanics of the respiratory movements caused by open pneumothorax. The decreased ventilation observed suggests some abnormality in the exchange of gases between the blood and the outside air. This will be considered in the next section.

3 The Respiratory Gas Exchange—The method adopted for the study of the respiratory exchange was that described by Benedict.² In the construction of our apparatus, we followed very closely the details of Benedict's description, into which it does not seem necessary to go now. Our oxygen was measured by a carefully calibrated Bohr gas meter, rather than by weighing. The animal was connected with the system by means of a three-way valve attached to the tracheal cannula.

The animals were of necessity under variable degrees of anesthesia. Because of the fatality of prolonged pneumothorax, the experiments were necessarily of short duration. Consequently, it was not possible to obtain values closely approximating a mean average. In order to obviate this statistical handicap, we have accepted only those experiments which, in the same animal, permitted one or more observations during alternate periods of one hour each of closed, open and closed thorax. In addition, only when the rectal temperature had remained close to normal were the experiments accepted. After many disappointments, experiments were accumulated that fulfilled these strict conditions in seven rabbits, in two of which the sequence was twice repeated, making a total of nine observations.

2 Benedict, F. G. *Deutsch Arch f klin Med* **107** 156, 1912.

The results of these observations are presented in Table 1. In Table 2 are presented the averages for all closed thorax periods, and for periods before, during and after pneumothorax, with no regard for the separation of the constituent figures into separate experiments. I have calculated the mean error of these averages by the usual formula, and in Figure 7, I have plotted these averages flanked by lines representing plus or minus three times the mean error. It is seen

TABLE 1—RESPIRATORY GASES AND QUOTIENTS IN PNEUMOTHORAX *

Exp No	Carbon Dioxid	Oxygen	Respiratory Quotient	Exp No	Carbon Dioxid	Oxygen	Respiratory Quotient
1	351 186* 149* 216	384 344* 208* 222	0.91 0.54* 0.55* 0.97	2	382 205* 398	559 446* 500	0.68 0.46* 0.79
3	274 302 288 166*	334 485* 320 310*	0.81 0.69* 0.89 0.52*	4	218 197* 239 196* 216	314 345* 345 332* 327	0.60 0.57* 0.60 0.59* 0.66
5	294 213* 309	344 374* 343	0.85 0.56* 0.89	6	369 295* 297 208* 394	510 460* 409 365* 490	0.72 0.63* 0.72 0.57* 0.79
7	377 390* 388* 485	508 552* 557* 544	0.74 0.70* 0.69* 0.89				

* Values for carbon dioxide and oxygen are in cubic centimeters per kilogram per hour. Values followed by * indicate pneumothorax periods. All periods are one hour each and immediately follow each other.

TABLE 2—AVERAGE RESPIRATORY GASES AND QUOTIENTS IN PNEUMOTHORAX *

	Carbon Dioxid	Oxygen	Respiratory Quotient
All closed thorax experiments	317 ± 25	401 ± 23	796 ± 22
Before pneumothorax	318 ± 19	414 ± 31	775 ± 28
During pneumothorax	241 ± 22	399 ± 25	593 ± 21
After pneumothorax	316 ± 91	389 ± 33	815 ± 30

* The values in Table 1 are averaged without respect to their separation into individual experiments. The mean error follows each average.

that the average value for oxygen remained practically unchanged. There was a considerable fall in the carbon dioxide average during pneumothorax, associated with a greater absolute fall in the respiratory quotient during the same period. The feature whose significance seemed most valid appeared in the respiratory quotient, in which the upper range of the pneumothorax period was below the lower ranges of all the other periods. Figure 8 presents the logarithms of these averages in order to bring out the ratio or proportional features of

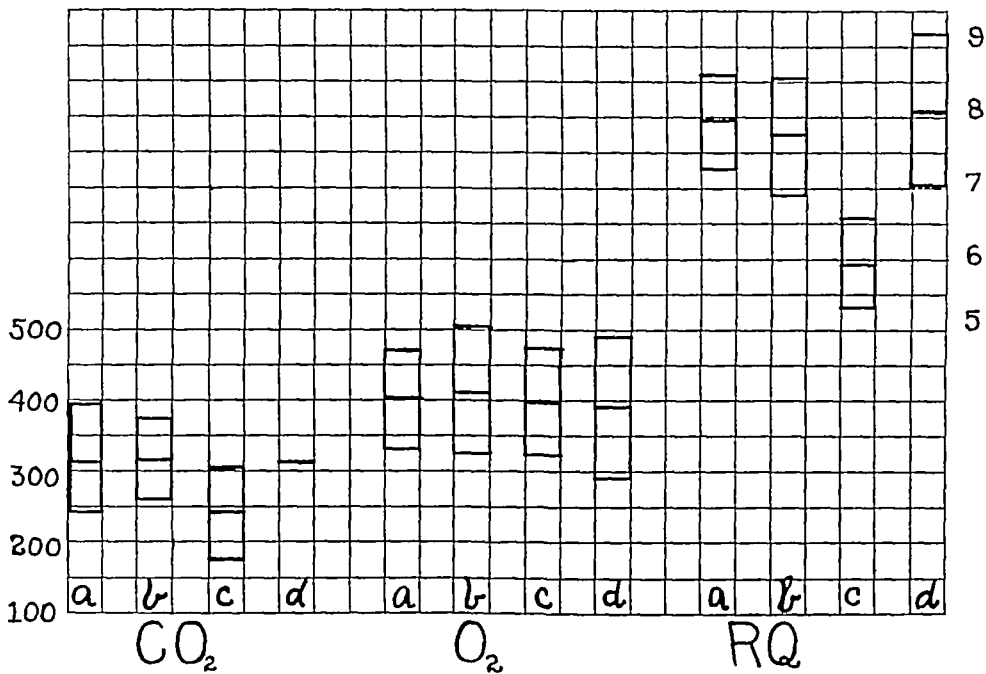


Fig 7—Average values of carbon dioxide, oxygen and respiratory quotient *a*, of all periods during which the thorax was closed, *b*, of periods immediately preceding pneumothorax, *c*, of pneumothorax periods, and *d*, of periods immediately following pneumothorax. The averages are flanked above and below by three times their mean error, except for period *d* of carbon dioxide values, in which the dispersion of the constituent values about the average is too great to render this method of presentation available

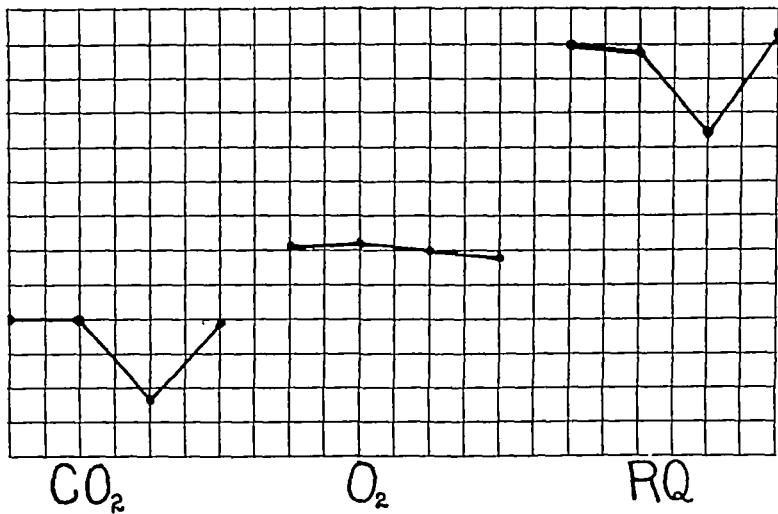


Fig 8—Averages of Figure 7 plotted on a logarithmic scale, so as to bring out the ratio features

the changes. It is seen that the ratio of change in carbon dioxide is not far below that of the respiratory quotient, the oxygen remaining practically unchanged.

Averaging all of the observations, without regard to their relation to one another in individual experiments, is, of course, the least favorable procedure. It is accordingly encouraging that this method yielded what it did. In Table 3 are presented the averages with their mean error of the ratios of values in individual experiments, before, after and of both together, to the values during pneumothorax. The individual constituents of the averages are also given. It is seen that the ratio of carbon dioxide, before or after pneumothorax, to its value during pneumothorax is less than 100 per cent in only three times out of nineteen. In these three instances it is only a little less, i. e., 90, 95 and 96 per cent. These values are probably insignificant,

TABLE 3—RESPIRATORY GASES AND QUOTIENTS IN PNEUMOTHORAX. RATIOS OF VALUES BEFORE OR AFTER TO VALUES DURING PNEUMOTHORAX. ‡

Carbon Dioxide		Oxygen		Respiratory Quotient	
Before	After	Before	After	Before	After
188	145	111	83	169	175
186	194	125	112	148	173
90	95	76	73	118	129
173	121	103	100	170	121
110	110	91	98	121	112
123	145	104	91	117	158
138	100	92	88	149	115
125	208	109	135	114	139
142	125	112	98	127	127
96		92		105	
137±10*	130±11*	101±4.1*	98±5.6*	133±7.0*	139±7.6*
136±7.7†		99±3.4†		130±5.4†	

* Averages

† Averages of all values, both before and after

‡ The values during pneumothorax are taken as 100

coming within the range of experimental error. For oxygen, ten values are below and eight above, with one at 100 per cent, indicating no marked preponderance of change either way. The respiratory quotient is in every instance higher when the thorax is closed. As to the averages, it is striking that the oxygen ratio remains practically at 100 per cent in all periods, while the averages of the ratios both before and after pneumothorax, for both carbon dioxide and the respiratory quotient are the same, 136 per cent. In Figure 9, I have plotted these averages of ratios, flanked by three times their mean error. In no instance does this range, either for carbon dioxide or for the respiratory quotient, extend down to the 100 per cent line. The average values and ranges for oxygen are quite well centered about the 100 per cent line.

In Figure 10, I have plotted the results of each experiment, again using the logarithms of the values in order to bring out the proportional changes. Each curve has its own base, but all are drawn to the same scale. These curves emphasize the extreme variability of the oxygen consumption and its relative small change from period to period. The much greater changes in carbon dioxide are brought out, together with the fact that in the few instances in which the value is higher during pneumothorax, it is only slightly so. In not a single instance does the quotient curve fail to fall during the pneumothorax periods, and usually quite markedly. It always rises after pneumothorax.

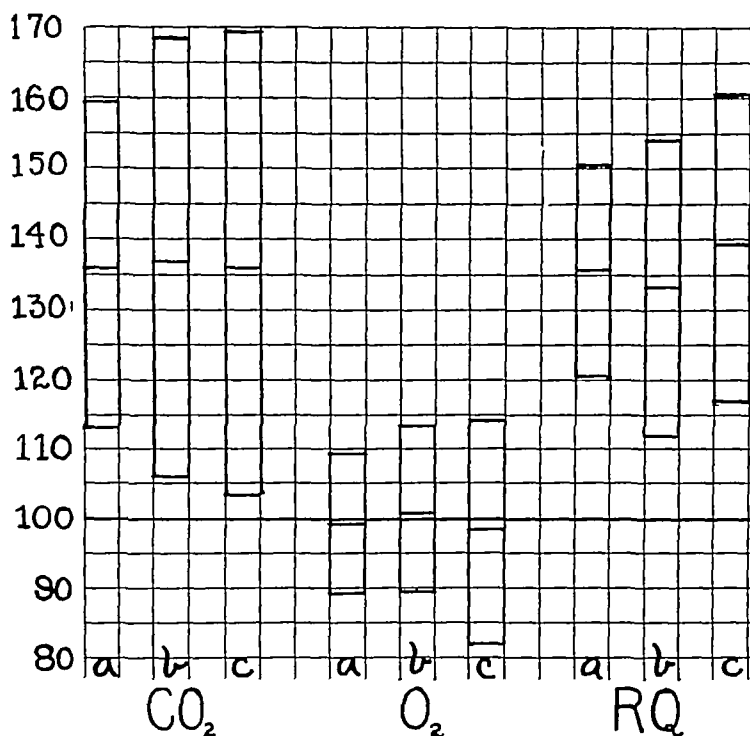


Fig 9—Averages of the ratios of carbon dioxide, oxygen and respiratory quotient, expressed in percentages, 100 per cent indicating the value during pneumothorax. *a*, average of all closed periods, *b*, before, and *c*, after pneumothorax. The averages are flanked by three times their mean error.

A large fall in the quotient is always accompanied by a large fall in the carbon dioxide output.

The presentation in so many different ways of the values found in these experiments has seemed justifiable because of the relative small number of experiments. It should be appreciated that to obtain a sequential series of experiments of this type is difficult, and many of our attempts have been failures. The results obtained indicate that there is a constant reduction of the respiratory quotient during periods of pneumothorax. This appears to be due chiefly to a fall in the output of carbon dioxide. The changes in the consumption of oxygen are

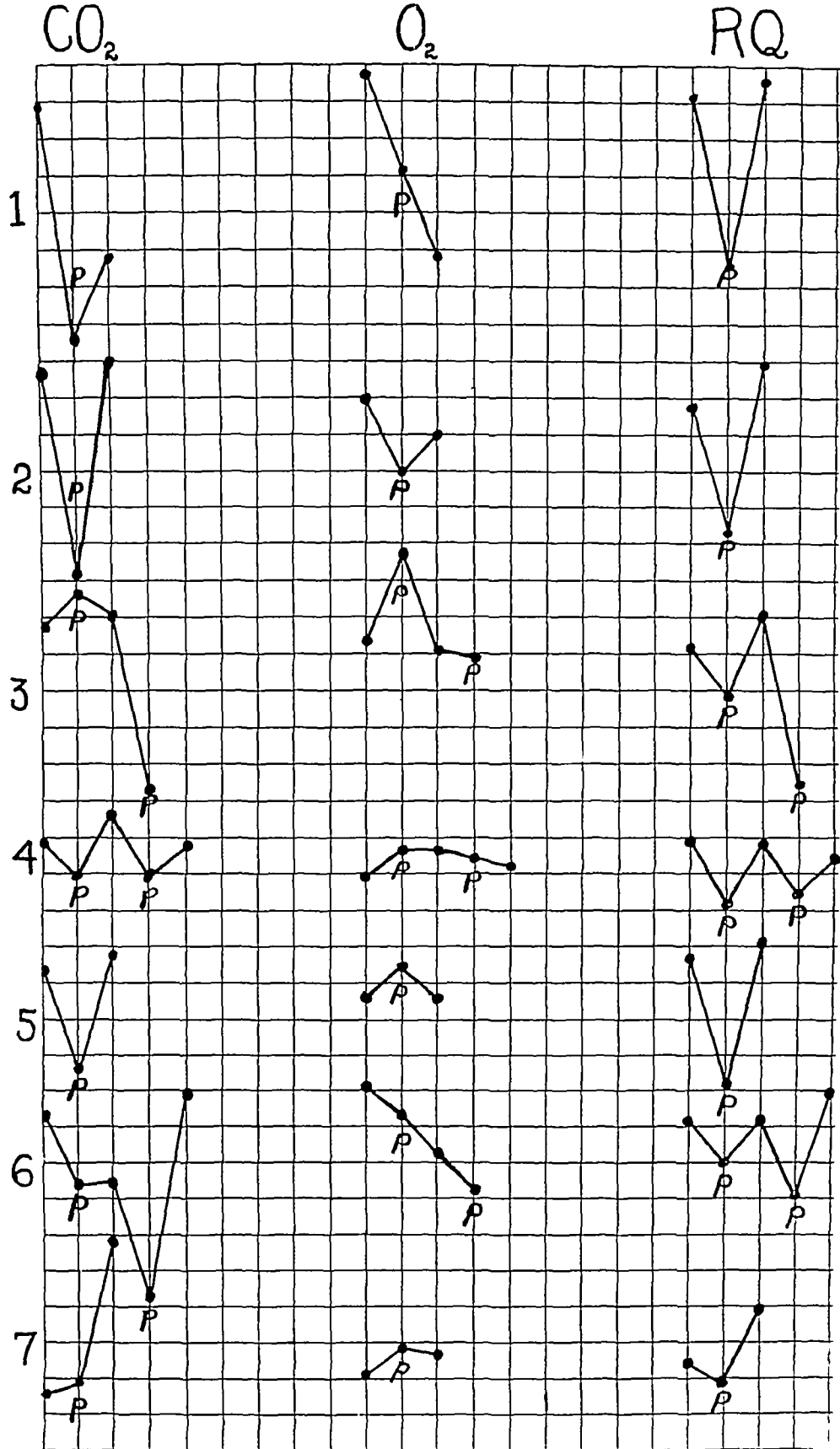


Fig 10—Values of the seven experiments plotted to the same logarithmic scale, but to different bases. Numerals at left indicate number of experiment. The dots labeled p indicate pneumothorax periods, unlabeled dots indicate closed periods.

of less magnitude, are more variable in direction, and seem not so intimately associated with the changes in the respiratory quotient

The significance of these results may be advantageously viewed in the light of contemporary physiologic theory. As the ventilation of the pulmonary alveoli decreases, the tension of carbon dioxide rises, and that of oxygen falls. Accepting the theory that the passage of these gases between the lung and the blood is a physical process of diffusion,³ at least over a wide range of functional demand, then the tension of these gases in the blood will tend to vary in the same direction as in the alveoli. In pneumothorax, the blood may be assumed to be exposed, as if *in vitro*, to an increased tension of carbon dioxide and a decreased tension of oxygen. In Figure 11 I have copied from Haldane, Meakins and Priestley⁴ the so-called dissociation curves

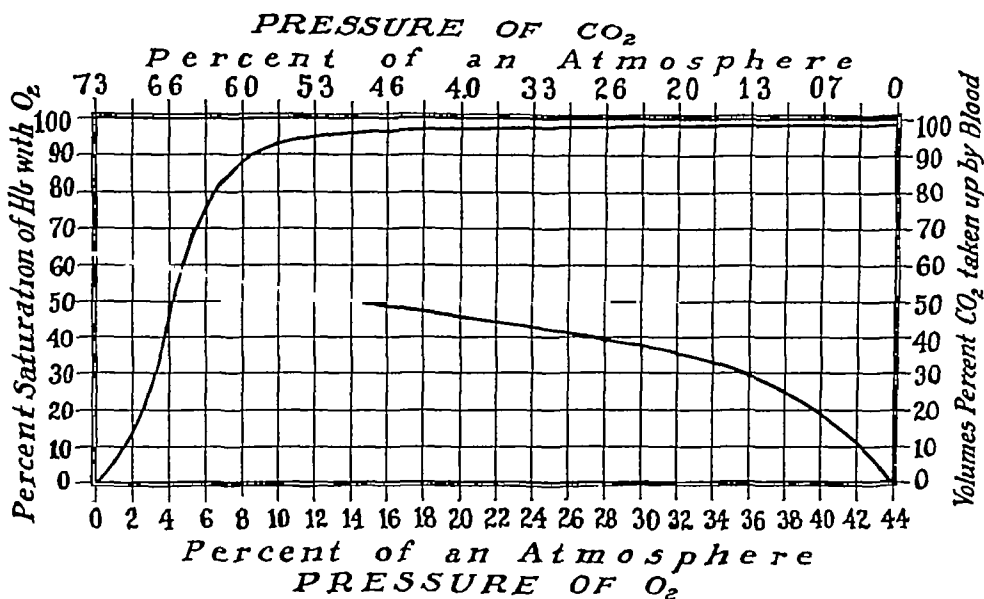


Fig 11—Dissociation curves for carbon dioxide and oxygen (copied from Haldane, Meakins and Priestley⁴)

for carbon dioxide and oxygen. These curves express the proportion between the amount of gas held by the blood in combination and the pressure or tension of the gas in the atmosphere to which the blood is exposed. The curve for carbon dioxide is, over a wide range, a steadily ascending straight line, indicating that as the tension is increased by equal increments the amount of carbon dioxide held by the blood in combination is increased by a certain fixed proportion. In other words, the blood has a large storage capacity for carbon

3 Barcroft, Joseph. *The Respiratory Functions of the Blood*, Cambridge University Press, 1914.

4 Haldane, J. S., Meakins, J. C., and Priestley, J. G. *J. Physiol.* **52**: 433 (May) 1919.

dioxid. However, the oxygen curve has a different conformation. Through a wide range it is almost horizontal, i. e., parallel with the abscissa. This means that as the tension of oxygen is decreased the amount of oxygen combined by the blood is decreased very little over a considerable range. Thus for a certain distance, conditions are adjusted for a more or less adequate absorption of oxygen, but for an increasingly impaired excretion of carbon dioxid. This situation is in harmony with the low respiratory quotients we have found to occur during pneumothorax. If the tension of oxygen is still further decreased, to a point where the curve begins to fall rapidly, then the absorption of oxygen tends temporarily to be decreased, so far as the blood becomes less saturated with oxygen. But this effect will be only transitory, since, within wide limits, the consumption of oxygen is regulated by the demands of metabolism, and not by the quantity of oxygen in the blood. That is, if the level of metabolic activity does not change, the necessary amount of oxygen will be removed from the partially saturated blood, and the blood will return to the lung in a higher degree of unsaturation than is normally the case. Its oxygen tension will be so low that in spite of the low tension in the alveolar air, an efficient slope of pressure will be maintained from the alveoli to the blood, and the consumption of oxygen will not be reduced. Such is the explanation of the values for oxygen absorption yielded by many of our experiments. Of course, if the reduction of oxygen tension in the alveoli becomes too low, the demands of the tissues will not be met and asphyxia will result. There is no evidence that this is a major factor in pneumothorax.

The invariability of the decrease of the respiratory quotient during pneumothorax seems entirely explainable by the above theory. This theory explains also the relatively constant decrease in carbon dioxide elimination. The variable amount of oxygen consumption, so far as it occurs beyond the limits of experimental error, would seem to find its usual explanation in the variable levels of metabolism associated with variable attempts at compensation on the part of the respiratory muscles. A lightly anesthetized animal, with an active respiratory center, will respond to pneumothorax with a strenuous respiratory effort, will demand more oxygen, and be able, up to a certain degree, to take in more oxygen. An animal too deeply anesthetized, or injured too much by the changes which occur in the blood as the result of the pneumothorax, will be capable of less respiratory effort, or may even approach respiratory failure, when, of course, oxygen consumption will be decreased. Carbon dioxide production will rise and fall with oxygen consumption, but the difficulty of its elimination will always lead to its accumulation in the blood and tissues. The few

small increases in carbon dioxide elimination that I have found during pneumothorax are probably within the range of experimental error. The constant fall of the respiratory quotient would indicate that the elimination of carbon dioxide is not in proportion to its production, and that accumulation in the blood must result.

This section may be summarized as follows. The absolute amount of oxygen absorbed varies in either direction, determined largely by the metabolic demands of the animal. While carbon dioxide production varies with the oxygen consumption, its elimination, at least relatively, and probably absolutely, is always reduced. The respiratory quotient is invariably decreased.

4 *The Carbon Dioxide Content of the Blood*—The retention of carbon dioxide shown by the study of the respiratory exchange suggested confirmation by the direct determination of the carbon dioxide content of the blood. These determinations were made by the Barcroft-Haldane apparatus⁵. The usual procedure of taking observations during alternating periods of closed and opened thorax was followed. The results are exhibited as part of Table 6. Comment is hardly necessary. The carbon dioxide content of the blood in all five experiments is higher during the pneumothorax period than in either the normal control period, or in the period of closed thorax after the pneumothorax. These results are in complete harmony with those of the previous section.

5 *The Acid-Base Equilibrium of the Blood*—The retention of carbon dioxide suggested the possibility that it might reach an amount sufficient to disturb the normal acid-base equilibrium of the blood and produce an acidosis in the sense of an increased hydrogen ion concentration. The dialysis-colorimetric method of Levy, Rowntree and Marriott⁶ was used. The blood was drawn from the carotid artery through a specially devised needle into a record syringe containing a little oxalate to prevent clotting. Three c.c. of blood were dialyzed for five minutes in tubes carefully stoppered. Many of the readings were taken independently by two observers. Control observations, before pneumothorax was induced, gave readings for p_H ranging from 7.35 to 7.5. After the production of pneumothorax, there was always a movement of the p_H toward the acid side, i. e., a reduction in its value. Values as low as 6.9 were observed. Such low values are, of course, only momentarily compatible with life, and the animals all died unless relieved by closing the opening in the

5 Barcroft and Haldane. *J. Physiol.* **28**, 233, 1902.

6 Levy, R. L., Rowntree, L. G., and Marriott, W. M. A Simple Method for Determining Variations in the Hydrogen-Ion Concentration of the Blood, *Arch. Int. Med.* **16**, 389 (Sept.) 1915.

chest The rate at which the acidity of the blood increased the degree it reached and the time of death of the animal varied considerably with different animals Some animals died in fifteen or twenty minutes with a very low p_H , i e., increased "acidity" Others lived more than an hour with little change in the reaction The cause of these variations is not certain It would seem that variable degrees of anesthesia would be one of the main factors Other factors are pliability of the mediastinum, age of the animal and diet

TABLE 4—HYDROGEN ION CONCENTRATION (p_H VALUE) OF THE BLOOD IN PNEUMOTHORAX *

Thorax						
Normal	Open	Closed	Open	Closed	Open	Closed
7.5	7.3	7.4	7.2	7.3		
7.5	7.3	7.5	7.3	7.4		
7.85	7.05	7.35				
7.3	7.15	7.2				
7.5	7.35	7.45	7.4			
7.6	7.25	7.45	7.2			
7.5	7.1	7.4	7.1	6.9	died in four minutes	
7.45	7.35	7.4				
7.5	7.4	7.5	7.4	7.5	7.25	7.3

* Each horizontal row of figures consists of the values observed during alternate periods of closed and open thorax in the same animal

The tendency toward acidity of the blood in pneumothorax was confirmed in nine out of a series of twenty-eight experiments in which the changes in the hydrogen ion concentration (p_H) were followed in successive and alternating periods of pneumothorax and of closed chest In nine, or approximately one third of these experiments a movement back and forth of p_H , corresponding to the alternate periods of closed and open chest, was obtained The results of these nine experiments are presented in Table 4 These results indicate a definite influence of pneumothorax on the reaction of the blood The inability to obtain such a correlated sequence in the rest of the experiments is explained by inopportune withdrawal of blood Probably many times the blood was taken too soon after the induction of pneumothorax and before the change in hydrogen ion concentration had taken place In some instances, the blood was undoubtedly taken so late that the animal either died or was unable to overcome the acidosis in the ensuing period of "closed thorax" In other words, the ratio of 1:3 successful sequences is mainly a measure of what might be termed the "clinical" judgment of the observer as to the condition of the animal at the time the various steps of the experiment were taken In Table 5 are given the results of four additional experiments, in which "clinical" judgment was aided by the simultaneous recording of the minute volume of respiration These results were read independently by two observers and show a small series in which

successful sequences were obtained in 100 per cent of the trials. Therefore it seems justifiable to conclude that the demonstration of such alternating changes in the hydrogen ion concentration of the blood in a considerable proportion of experiments is proof of the intimate relation of pneumothorax to these changes, i. e., associated with pneumothorax there is an acidosis in the sense of an increased hydrogen ion concentration (reduced p_H).

TABLE 5— p_H VALUES IN FOUR SUCCESSIVE EXPERIMENTS CONTROLLED BY RECORDING MINUTE VOLUME OF RESPIRATION

Control	Thorax Open	Thorax Closed
7.85	7.05	7.15
7.45	7.15	7.35
7.35	7.25	7.4
7.4	7.2	7.4

TABLE 6—CARBON DIOXID CONTENT AND REACTION OF THE BLOOD IN PNEUMOTHORAX

Exp. No.		Thorax				
		Control	Open	Closed	Open	Closed
1	Vol. % CO ₂	47	60	54-60	60	47
2	Vol. % CO ₂	70	77	56	90	*
	p_H	7.35	7.1	7.05	7.05	
3	Vol. % CO ₂	63	95	73		
	p_H	7.4	7.15	7.35		
4	Vol. % CO ₂	49	73	53-50		
	p_H	7.35	7.25	7.25-7.4		
5	Vol. % CO ₂	53	70	55		
	p_H	7.4	7.2	7.4		

* Animal nearly died at first pneumothorax.

The previous experiments having shown that there is in pneumothorax an accumulation of carbon dioxide in the blood and an increased hydrogen ion concentration, it seemed desirable to secure simultaneous data as to the association of these two factors. Five experiments were performed, following the usual sequential alternation. Here again were encountered the technical difficulties of a procedure which brought the animal close to death during the pneumothorax periods. Nevertheless, in the last three experiments, the correlation of chest condition with the carbon dioxide content and the hydrogen ion concentration of the blood is quite close. In the second experiment the animal nearly died several times, and the p_H values were not obtained in the first experiment. It should be added that the determinations of the p_H and of the volume per cent of carbon dioxide were not strictly simultaneous, there often being an interval of several minutes.

Taking into consideration all of the evidence presented as to the retention of carbon dioxide and the appearance of an increased hydrogen ion concentration of the blood during periods of pneumothorax, it would seem permissible to conclude that an "acidosis" develops which, in part at least, is due to the retention of carbon dioxide. That in addition there may appear fixed acids, we were unable to determine. The oxygen consumption in some of the experiments was low, and, in relation to the metabolic demands, may have been sufficiently low to produce asphyxia of such a degree as to permit the appearance of unoxidized acid metabolites. Direct proof of the presence of fixed acid was sought by determining the hydrogen ion concentration after freeing the blood of its carbon dioxide by means of a vacuum, and then exposing it to a constant tension of carbon dioxide. The results were wholly equivocal. It is suggestive that during the intervals of closed chest after pneumothorax the blood carbonate was never very low. Such would be the case in the presence of fixed acids, since these would tend to displace the carbon dioxide from union with base, raise the amount of free carbon dioxide and its tension in the blood, and hasten its excretion through the lung. It may be objected that the time interval was too short for the washing out of the carbon dioxide to a low level. In only one instance during periods of from twenty-five to sixty minutes did the total carbon dioxide content fall below 50 per cent by volume. While it does not seem likely that fixed acids play a great rôle in the production of the acidosis of pneumothorax, their existence cannot be disproved by the data here submitted.

We conclude then that an "acidosis" appears during pneumothorax, associated with, and in large part due to, a retention of carbon dioxide. The rôle of fixed acid is not solved.

IV CLINICAL CORRELATION AND COMMENT

The direct transfer to man of the results obtained in this investigation on the rabbit cannot be made without due consideration of existing physiological differences. Being herbivorous, the rabbit is more susceptible to acid intoxication, because it is less able to deviate ammonia from urea formation in order to neutralize acid. While the effect of pneumothorax on the minute volume and the respiratory exchange would quite likely be similar, it would seem that the appearance of an acidosis associated with an increased carbon dioxide content of the blood would be at least more fully compensated for in the carnivora. At any rate, it is interesting to apply the analogy to the problems encountered in the clinic.

The most common clinical procedure which produces a mechanical respiratory condition analogous to experimental pneumothorax in the rabbit is the operation for empyema. It is the experience of surgery

that patients may die during operation for empyema because of rupture of pus into a bronchus, with flooding of the lungs. According to Capps and Lewis⁷ the cause of death may sometimes be due to reflex stimulation of the vagus, especially when the custom of washing out the pleural cavity is practiced. However, there is another type of death, which is not so sudden, and which usually occurs after the patient has been returned to the ward. An explanation of this type of death is suggested by the experimental work just reported. I refer to the patient who has been rolled partly over and the thorax quite well drained of pus. A large open tube has been placed in the opening in the chest wall, and the exposed end covered with a dry gauze dressing. Here we have all the conditions of an open pneumothorax, with air rushing in and out of the tube. There are several possible reasons why the mortality has not been greater. First, unless the empyema is an early one, the mediastinum is stiffened by the inflammatory exudate and invasion, so that the lung on the sound side is competent to meet the respiratory demands. Second, if the pus is not too thoroughly emptied at the time of operation, it will soon fill the tube and saturate the dressings, and thus prevent the free exchange of air through the tube. I have had two experiences with patients who were doing badly with dry open drainage tubes, but who improved by simply clamping the tube. In children, especially, is this condition likely to develop, due perhaps to the greater pliability of the mediastinum, which permits the effect of a unilateral pneumothorax to be more readily transmitted to the sound lung. General anesthesia, by lowering the activity of the respiratory center, would tend to augment the dangers.

The results of this work as applied to the operation for empyema would suggest these advantageous procedures

- 1 In early cases the aspiration of the pus through a needle for a few days in order to allow time for stiffening of the mediastinum

- 2 The use of local, instead of general, anesthesia

- 3 Closer observation of the patients for the first few hours after operation

- 4 The incomplete removal of pus at the operating table

- 5 The temporary application of a Politzer bag to the drainage tube, by which a "sucking" wound is prevented and into which the pus may drain

⁷ Capps, J. A., and Lewis, D. D. Blood-Pressure-Lowering Reflexes from Irrigation of the Chest in Empyema, *Arch Int Med* 2 166 (Sept.) 1908, *Surg Gynec & Obst* 7 243, 1908

6 The probably unnecessary refinement of the use of negative pressure per se

In any case it will not be long before the formation of adhesions and the plastic exudate will prevent the development of this condition

The ability to operate on the lung without the use of positive intrapulmonary pressure may be raised as evidence against the possible occurrence in man of the conditions found in these experiments. However, it must be pointed out that when the lung itself has been the site of exploration or operation, it has usually been pulled up into the pleural opening, thus preventing an open sucking pneumothorax. Further, it is to be remembered that a considerable time interval is necessary for the development of this condition, even in the rabbit. In any case it should be borne in mind that the major danger lies neither in the collapse of the lung, nor in a closed pneumothorax, but in the deviation of the muscular respiratory effort, normally used to move air in and out of the trachea, to the moving of air in and out of the pleural opening.

V CONCLUSIONS

1 Experimental open pneumothorax in rabbits causes an intense dyspnea, provided the anesthetic is not too deep, and death, if unrelieved by closure of the thoracic opening.

2 The volume of air respired per minute is decreased despite the increased respiratory effort.

3 The rate of oxygen consumption is variable, due probably to variable compensatory muscular action rather than to impaired gaseous exchange between lung and blood.

4 The excretion of carbon dioxide is impaired, often to a great degree.

5 The respiratory quotient is constantly reduced.

6 There is an increase in the total carbon dioxide content of the blood and at the same time an increase in the hydrogen ion concentration.

7 These functional changes are important in open chest wounds in the operation for empyema and related surgical conditions.

Since sending this manuscript to the publisher my attention has been called through a recent article to the work of Everts A. Graham and Richard D. Bell, published in the War Medicine Supplement of the *American Journal of the Medical Sciences*, pp 156-839, December, 1918. They report an extended experimental study of the relation between the pressure within one pleural cavity and changes of pressure artificially produced within the other pleural cavity. They show a close correspondence. My view based on only a few experiments and on a theoretical deduction from the visible flaccidity of a considerable portion of the mediastinum is in entire agreement with theirs.

They have also studied the influence of the size of the pleural opening, showing that up to a certain size the condition is not fatal. It may be well to repeat that in my work the same pleural and tracheal cannulas were used in all the experiments, and were so related in size that the pneumothorax was always fatal, unless relieved.

This work was made possible by the facilities offered by the Cushing Laboratory of Experimental Medicine, the Physiological Laboratory of Western Reserve University, and the laboratories of the university clinic at the Cleveland City Hospital.

OBSERVATIONS ON THE BLOOD PRESSURE IN CASES OF PROSTATIC OBSTRUCTION

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During the last two years we have made a study of the blood pressure changes which occurred during the hospital management of patients suffering from prostatic obstruction

The original object of these observations was to obtain, if possible, additional data which might assist us in determining the most advantageous method of preparing such patients for operation as well as the most suitable time for undertaking such an operation. Also, observations on the blood pressure of patients who have been relieved of their urinary obstruction for some time have revealed findings worthy of note

This report comprises the results of the study of fifty-six patients with urinary retention due to prostatic obstruction, fifty-five of whom were operated on. The average age of this group was 61 years. The oldest patient was 86 and the youngest 46 years of age.

Prior to the estimation of the amount of residual urine, the blood pressure reading was recorded. A blood pressure reading was made every twenty-four hours for four days, and then every second day during the patient's stay in the hospital. Whenever possible the same house officer made all the readings throughout the entire hospital management of the individual case. He used the same standard type of mercury manometer to record all of the readings.

EFFECT OF DRAINAGE OF THE BLADDER

Sudden Fall in Blood Pressure —When the bladder is kept at complete rest by an indwelling catheter, or by suprapubic cystotomy, a very appreciable fall in blood pressure occurs during the first twenty-four hours. In this series, the average fall in systolic blood pressure was 40 mm of mercury at the end of this time. The average fall in diastolic blood pressure was 14 mm of mercury.

The most marked diminution occurred in those patients who presented themselves with a marked hypertension, in nearly every instance associated with a considerable amount of residual urine (400 or more cubic centimeters). To a great extent the degree of fall seemed to depend almost entirely on two things: the quantity of residual urine, and the degree of reduction of renal function. The presence or absence of infection of the urinary tract made no obvious

difference in the degree of blood pressure change, nor was there any relative difference noted between those patients drained by suprapubic cystotomy and those in whom drainage had been established by an inlying urethral catheter. In all cases, when possible, the patient was urged to sit up in a chair for a time each day, and in most instances to walk about.

The greatest drop in systolic pressure during the first twenty-four hours after constant drainage was 85 mm., and in diastolic, 45 mm.

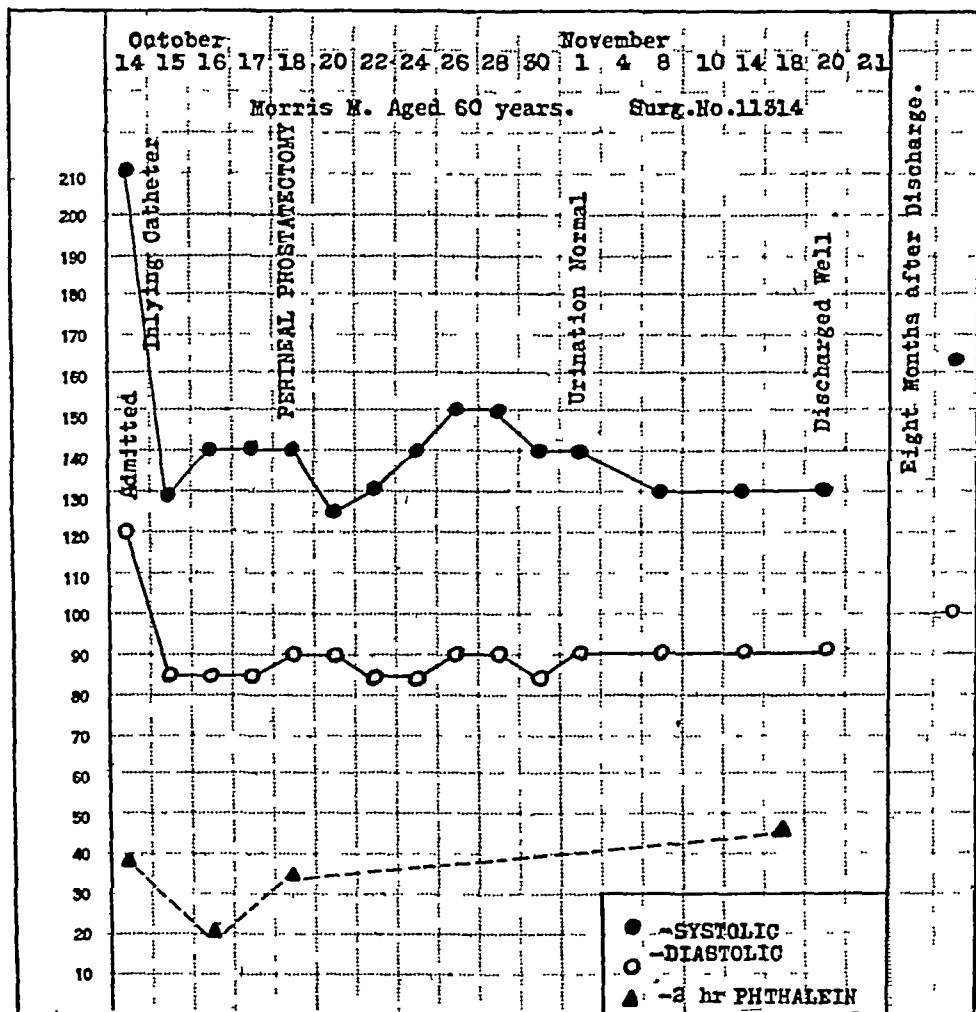


Chart 1—Sudden fall in blood pressure on constant drainage with a rapid subsequent establishment of a fixed level. Postoperative fall was insignificant.

In 25 per cent of the cases there was no fall in diastolic pressure at all, although 15 per cent of these patients had an appreciable decrease in the systolic pressure. The six patients in whom there was no blood pressure change following drainage were all persons with a very small amount of residual urine, four of whom had an obstruction of the so-called "median bar" type.

In no instance did the blood pressure readings show an elevation on the second day as compared with the first day after keeping the bladder at rest. In 60 per cent of the cases the systolic blood pressure continued to fall during the second twenty-four hours with an average of 17 mm of mercury. In 40 per cent there was no further reduction in systolic pressure and in 85 per cent no decrease at all in diastolic pressure during this time.

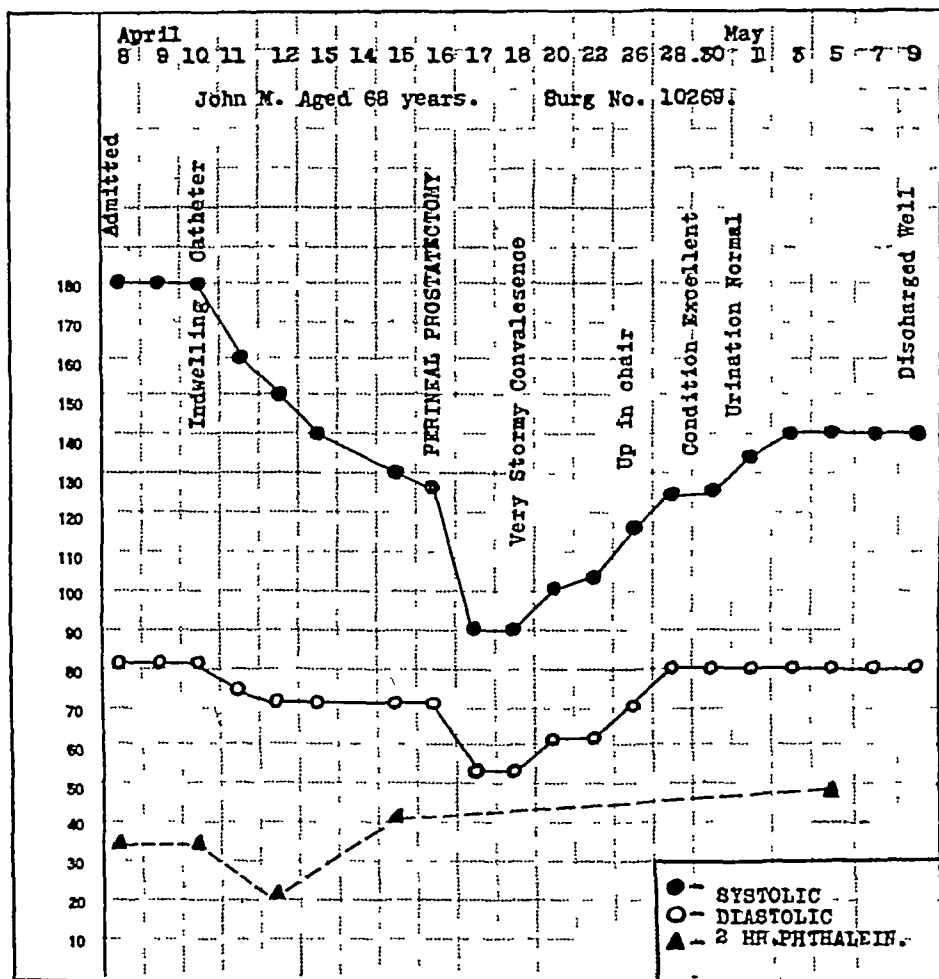


Chart 2—Gradual fall in blood pressure on constant drainage. Operation, undertaken while the pressure was still falling, resulted in a marked decrease in pulse pressure.

There was no further fall in blood pressure in 75 per cent of these cases after the second day of drainage. However, in the remaining 25 per cent the pressure did continue to fall for one or several days and averaged a total decrease during this time of 15 mm of mercury.

It was early noted that patients operated on at a time when the blood pressure was still showing a slight decrease each day, even though the pressure was accompanied by satisfactory renal function, showed a postoperative fall in blood pressure greater than seemed normally commensurate with the degree of operative disturbance

This suggested the possibility that we were operating on these patients without a sufficiently prolonged preoperative management,

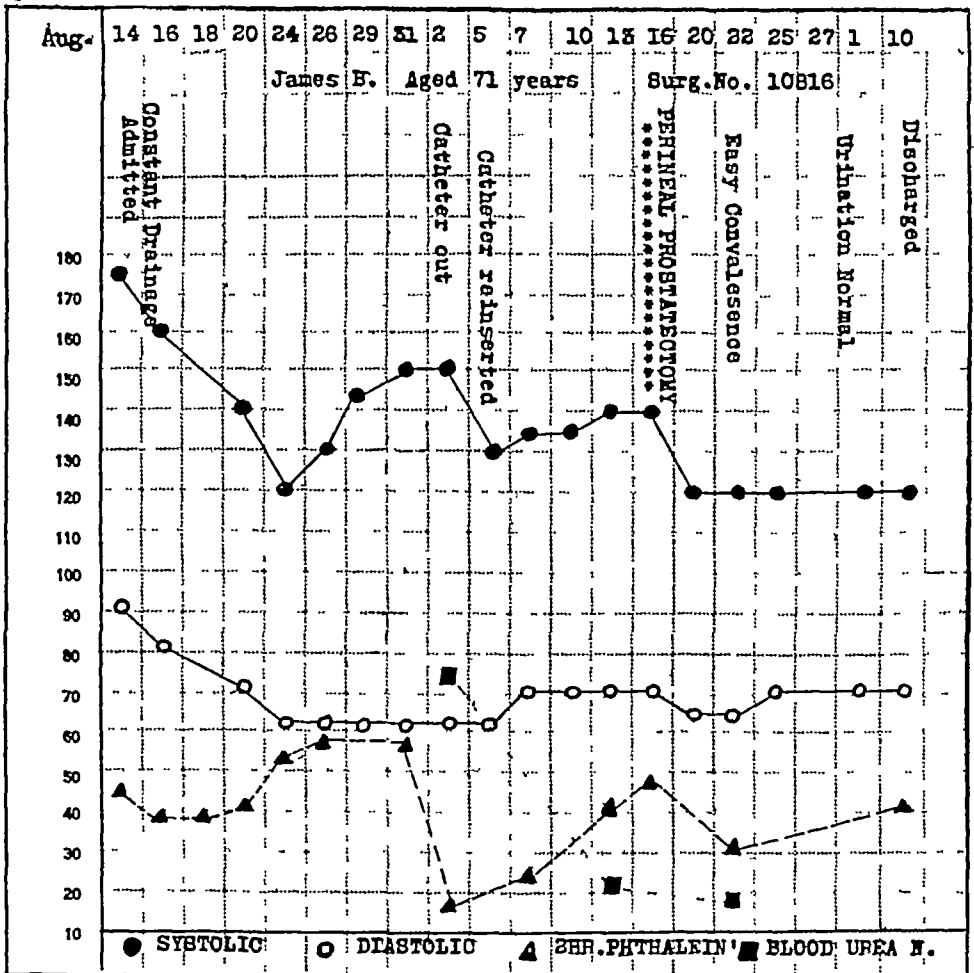


FIGURE 3

Chart 3—Gradual fall in blood pressure on constant drainage with subsequent rise Cessation of drainage for twelve hours was accompanied by a sudden fall in blood pressure associated with a marked decrease in renal function when the catheter was reinserted

despite the fact that their general condition seemed satisfactory and their renal function entirely adequate So, after this observation and in order that we might draw conclusions, no patient was operated on until his blood pressure had maintained a definite level for at least four days

Establishment of a Fixed Blood Pressure Level on Continued Drainage—When the patients were kept on satisfactory drainage, 60 per cent of them had a subsequent rise in blood pressure after the period of decline. This average rise in systolic pressure was 16 mm and in diastolic, 5 mm of mercury.

In all but two patients observed, the blood pressure reached a constant level in from four days to two weeks and did not vary from this level over 5 mm of mercury in the daily readings regardless of the duration of the drainage period. It must be emphasized, however, that any interruption, or insufficiency, of drainage for a period of more than from six to eight hours will frequently bring about very marked and rapid changes in the blood pressure and renal function. In the rare instance in which this interruption occurred, a reproduction of the entire series of relative blood pressure changes occurred in the same manner as when the patient was first placed on drainage, except that a fixed level was reached in a much shorter period of time.

The conclusions to be drawn from these observations are that on continued drainage of the bladder the blood pressure within two weeks maintains a level, or "equilibrium," at which time the renal function is restored to the greatest extent possible, and that the patient is in the best general condition for operation. This new level is in the great majority of instances a definitely lower one than that existing before drainage was established.

Postoperative Fall in Blood Pressure—In the four cases in which operation was performed while the blood pressure was still falling, the decrease in systolic pressure during the first twenty-four hours after operation averaged from 80 to 30 mm of mercury and from 40 to 5 mm, diastolic. There was therefore a considerable reduction in the pulse pressure, and rigorous postoperative management was necessary to return these patients to a normal convalescence. Whereas in those patients who had been prepared for operation until the blood pressure had maintained a definite fixed level, the degree of postoperative fall was surprisingly insignificant, 25 per cent having no decrease in blood pressure at all and the average total fall in the remainder being 10 mm, systolic, and 6 mm, diastolic. There was therefore practically no change in the pulse pressure and the immediate convalescence was relatively easy.

Convalescent Period—The relative blood pressure changes after operation varied considerably. Twenty per cent of the patients had no subsequent rise and were discharged from the hospital with the blood pressure at the same level as it had been twenty-four hours after operation. The rest had a subsequent rise of from 10 to 40 mm of mercury. In only one instance did a patient leave the hospital with

a higher blood pressure than he had had before preliminary bladder drainage Ten per cent left the hospital with the blood pressure at the same level as it had been on admission The rest were discharged with the systolic blood pressure ranging from 80 to 15 mm of mercury lower than before being placed on bladder drainage

Subsequent Blood Pressure—The blood pressure readings of thirty of the patients in this series have been recorded since their discharge

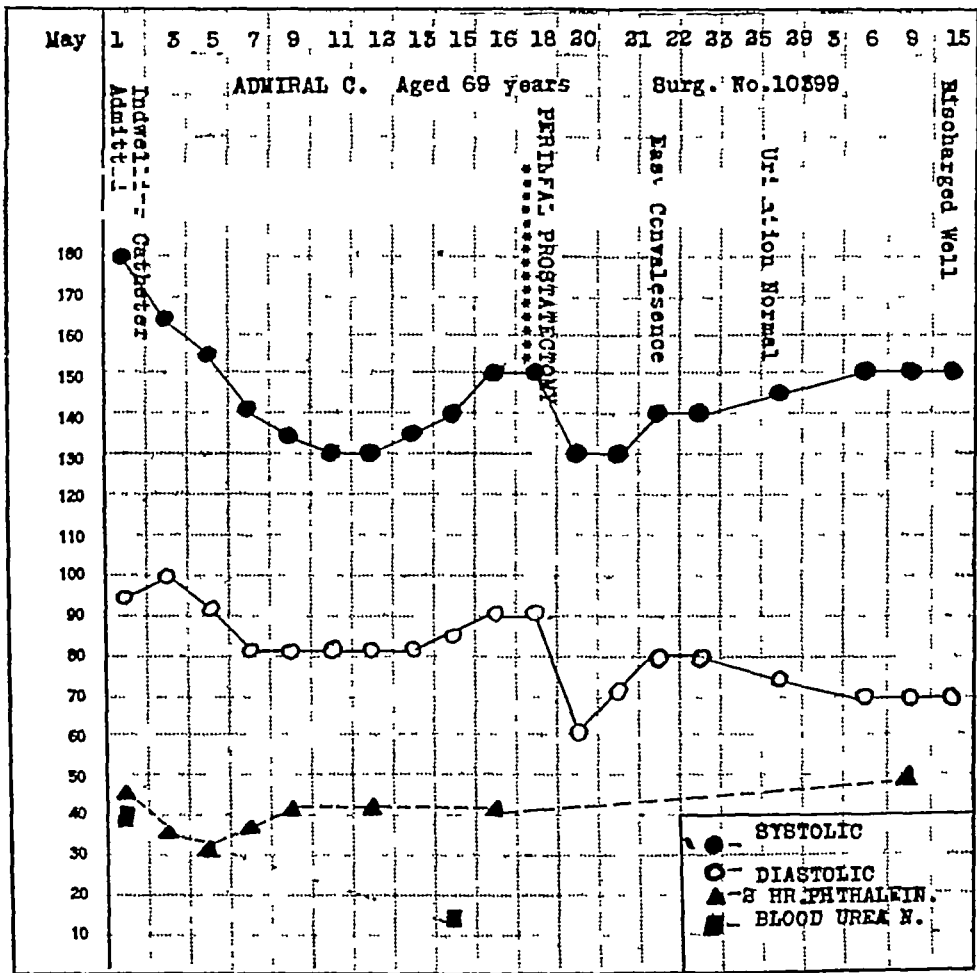


Chart 4—Gradual fall in blood pressure on constant drainage associated with marked improvement in renal function Operation caused no decrease in pulse pressure.

from the hospital The period of observation has ranged from one to seventeen months

Two patients now have a systolic pressure 20 mm higher than before the urinary retention was relieved, but neither of these patients has a blood pressure higher than that which would be considered normal for his age

Five patients have a systolic pressure maintaining the same level which was recorded on their original admission for treatment. Only two of these have an abnormally elevated blood pressure, and in both there is definite cardiac hypertrophy with valvular disease.

Twenty-three of these patients have a blood pressure which has continued at practically the same level as that which was estimated on their discharge from the hospital. On comparing their present blood

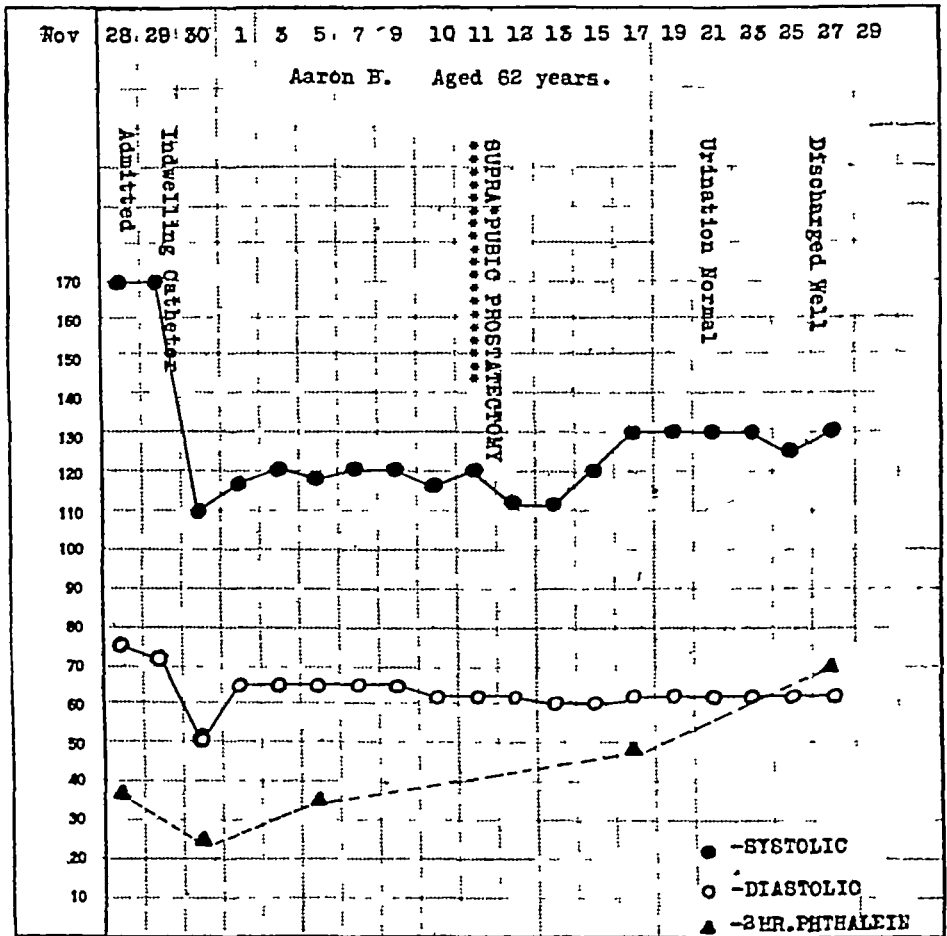


Chart 5—Sudden fall in blood pressure on constant drainage with rapid establishment of a fixed level. Very slight postoperative fall in pulse pressure.

pressure readings with those made prior to any attempt at the relief of the urinary retention, we find that their systolic pressure is now maintained at a level which shows an average decrease of from 65 to 10 mm of mercury. Of this number, sixteen patients had a definite hypertension with a systolic blood pressure ranging from 290 mm to 160 mm of mercury before bladder drainage had been instituted. Of these, only two patients now have an abnormally elevated blood pres-

2 If satisfactory drainage of the bladder is continued, the blood pressure is gradually maintained at a definite, nonfluctuating level. During this period the adequacy of the renal function and the general condition of the patient indicate that he is in the best possible condition for operation.

3 Patients prepared for operation by waiting until this fixed blood pressure level has been established have shown a very insignificant postoperative decrease in blood pressure.

4 The majority of these patients who had suffered from long standing urinary retention, and who originally presented themselves with a hypertension, have continued thus far to be relieved of their abnormally high blood pressure except in a few instances in which demonstrable cardiac disease existed.

SURGICAL EXPERIENCES WITH AN INTRACRANIAL APPROACH TO CHIASMAL LESIONS *

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In May, 1914, an intracranial operation for exposing chiasmal lesions was devised and successfully performed on a patient with an hypophysial cyst. It was unlike the procedure of Krause, McArthur and the earlier operation of Frazier, in that it was an intradural rather than an extradural approach. It antedated the later operation of Frazier and the procedure of Adson—operations which, although differing in some details, are in principle the same. It has been consistently employed in lesions suitable for its use, first, because, at the time it was devised a serious trial of an intracranial approach had never been made, and second, because of the desire to learn whether such an approach offered more in the treatment of chiasmal lesions than does the popular nasal approach. Between 1914 and 1918, thirty-seven patients with chiasmal lesions have come to us for treatment. Six patients were not treated, either because operation did not seem indicated or because they refused operation. On two patients a simple decompressive craniotomy was performed for the relief of pressure symptoms, on five patients a transsphenoidal operation was performed, and on twenty-four patients the intracranial operation I shall subsequently describe was performed. On six of these patients a second intracranial operation was performed from one and a half to three years after the primary operation¹. The series, then, is rather small, yet from a survey of the literature, it is the largest individual series in which an intracranial operation has been consistently used.

What knowledge have we gained by an intracranial exposure of the nature, the direction of growth, the clinical aspects and the accessibility of chiasmal lesions? How does this knowledge apply in determining what route—intracranial or transsphenoidal—to use in those who present symptoms and signs of a chiasmal lesion?

THE NATURE OF CHIASMAL LESIONS

The chiasmal lesions—using the term in a broad sense to indicate those tumors or cysts which arise in or about the optic chiasm—include the hypophysial tumors and cysts, the optic chiasm tumors

* Read before the Section on Surgery, General and Abdominal, at the Seventy-First Annual Session of the American Medical Association, New Orleans, April, 1920

1 Of the thirty operations performed on these twenty-four patients, nine were performed by Dr W E Dandy and twenty-one by myself

and the suprasellar tumors and cysts. In our experience hypophysial lesions occurred in 73 per cent, suprasellar lesions in 24.3 per cent, and optic chiasm lesions in 2.7 per cent of the cases.

These percentages probably more truly represent the proportion of these lesions than do those in the literature at present. Fully 90 per cent of the cases in the literature are reported as hypophysial lesions, yet when we read the operative reports and the findings in necropsy examinations it is clear that many cases reported as hypophysial and in which operation was performed by the nasal route were suprasellar lesions. This point is of considerable importance, it indicates the difficulty that has been experienced in differentiating between hypophysial and suprasellar lesions, and it suggests that surgeons have heretofore been attacking indiscriminately by one approach all lesions about the chiasm.

Pathologically, the lesions in our series were made the subject of a special study by Duffy, the results of which are—Of the twenty true hypophysial lesions in which operation was performed, solid tumors occurred in 80 per cent, cystic tumors in 20 per cent. In 100 per cent of the solid tumors the diagnosis of adenoma was made. In all of the cystic tumors, adenomatous tissue was demonstrable in the walls of the cysts. True cysts of the hypophysis therefore did not occur in this series. Of the seven suprasellar lesions in which operation was performed, three were solid tumors (gliomas of the anterior perforated space, or base of the brain), three were cysts arising from cell inclusions of the craniopharyngeal duct, and one a solid and cystic tumor (glioma) arising from the base. The one lesion of the optic chiasm in this series was a sarcoma arising from the nerve sheath. These findings emphasize what the more recent literature on the pathology of chiasmal lesions has indicated, namely, that with increasing knowledge more and more cases which were previously diagnosed as carcinoma, sarcoma, epithelioma, malignant adenoma, and endothelioma of the hypophysis are now recognized as adenomas, and that perhaps 50 per cent of the suprasellar lesions are cysts arising from embryonic inclusions of the craniopharyngeal duct.

DIRECTION OF GROWTH

It is well known that in the early period of their growth hypophysial lesions are confined within the sella turcica. Sooner or later, however, they extend beyond the confines of the sella and their growth is either downward, toward or into the sphenoidal sinus, or upward into the intracranial chamber. It has been assumed, from the fact that at transsphenoidal operations the floor of the sella turcica has been found thinned or completely absent, that the direction of growth is primarily downward, and one of the arguments used in favor of

the transsphenoidal approach has been that it permits, by removal of the floor of the sella turcica, the downward growth of hypophysial lesions. It is indeed true that hypophysial lesions are found filling the sphenoidal sinus, but that their growth has been primarily in this direction, or that it has occurred to a greater extent in a downward rather than an upward direction seems to us incorrect. In my examina-

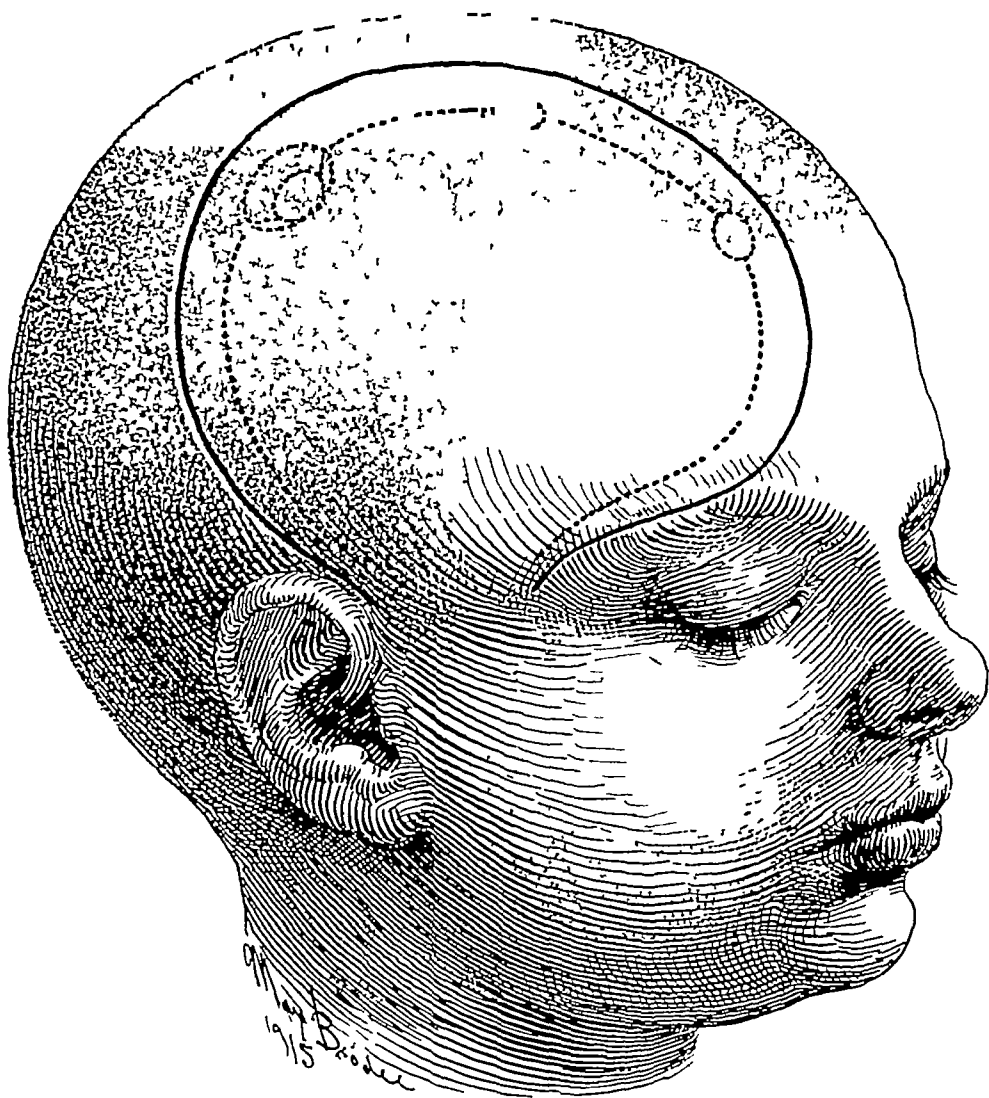


Fig 1—Outline of scalp and bone flap in the approach to the chiasmal region

tion of reports in the literature of cases in which the patients died after transsphenoidal operations, I have found that in practically 100 per cent of the cases—even though the floor of the sella turcica has been eroded and the tumor fills the sphenoidal cavity—a far larger proportion of the tumor has extended into the intracranial chamber. Moreover, our

personal experience in viewing hypophysial lesions through an intracranial approach has demonstrated two important points. First, that before the floor of the sella turcica has been eroded and even before the posterior clinoid processes have become destroyed, the hypophysial lesion has broken through the diaphragm of the sella turcica and become an intracranial growth, and second, that even though the floor of the sella turcica is removed by early operation conducted through the nose, the lesion will not, or only to a slight extent, grow downward, but will in spite of these measures grow upward into the intracranial chamber. It seems evident to us, therefore, that the diaphragma sellae offers the least resistance to the growth of hypophysial lesions and that their growth is primarily and always in greatest extent upward and into the intracranial chamber.

Their direction of growth after hypophysial lesions have broken through the diaphragma sellae has been the subject of investigation, and from an operative standpoint the determination of this point is of great importance. Obviously, hypophysial lesions may grow directly upward toward the base of the brain, they may grow forward, appearing in front of the optic chiasm and between the optic nerves, they may grow backward behind the chiasm and extend posteriorly in the cleft between the base of the temporal lobe and pons, and finally, they may grow laterally into the temporal fossae and involve the cavernous sinuses. From the literature, we gather that hypophysial tumors have been found at necropsy extending in all these directions, but owing to the incompleteness of the reports, and to the fact that postmortem examinations have been made chiefly in late cases, it cannot be determined in what special direction, if any, these lesions primarily grow. Cope, on anatomic grounds and from a study of the literature, concludes that the early intracranial extensions of hypophysial tumors are forward in front of the optic chiasm, and our personal experience is overwhelmingly in support of his findings. In twenty-two intracranial exposures of true hypophysial lesions the intracranial extension was forward—appearing in front of the optic chiasm and between the optic nerves—in twenty instances, and was forward and laterad in two instances. In four of the cases in which the lesion appeared forward, a second exposure made one to two years after the primary, again disclosed the lesion appearing forward. Extension backward did not occur in our moderately early cases. Our necropsy examinations confirm these operative findings. Moreover, the diagrams of Schloffer and the more recent diagrams of the operative findings in Adson's six cases, support our observations, and I believe it may be stated, therefore, that the early intracranial extensions of hypophysial lesions are forward and appear in front of the optic chiasm between the optic

nerves From the point of view of operative procedure, the importance of this point is that the forward intracranial extensions of hypophysial lesions are readily accessible by intracranial operations

The suprasellar and the chiasmal lesions need not be discussed from this standpoint They are primarily intracranial tumors and can be satisfactorily approached only by an intracranial route

CLINICAL ASPECTS OF CHIASMAL LESIONS

From a clinical point of view, cases which present symptoms of a chiasmal lesion may be roughly grouped as follows

1 A group of cases which present evidence of disturbed hypophysial function either on the side of lessened activity (obesity, sexual abnormalities, drowsiness), on the side of increased activity (early acromegaly), or mixed types There are no discomforts, such as headache, and there are no neighborhood symptoms (pressure on the chiasm) The sella turcica may be normal in size, it may be small or it may be enlarged It does not show any destruction Up to the present time, surgery in this group of cases has not been considered indicated

2 A group of cases with glandular symptoms (acromegaly or mixed glandular symptoms) and with pronounced sellar headaches There may be slight visual disturbances, as evidenced by contraction of the visual fields, but no hemianopia The sella may be enlarged but shows no evidence of destruction nor alteration in the distance relations between anterior and posterior clinoid processes It has been assumed that the struma, if such it be, is confined to the sella turcica and has not invaded the intracranial space Surgery may attempt in this group to relieve the headaches Whether it should attempt more, such as the removal of a part of the gland, has seemed doubtful

3 A group of cases with pronounced "neighborhood" symptoms (various forms and degrees of hemianopia, optic atrophy, diminished visual acuity, ocular palsies) There may be evident glandular symptoms of the acromegalic, Froelich, or mixed types, or glandular symptoms may be absent The sella turcica is enlarged and has undergone varying grades of destruction This group of cases has been considered most favorable for surgery, and operative procedures—in the vast majority of cases conducted through the nose—have been directed to relieving the neighborhood symptoms, only incidently to correcting secretory abnormalities

4 A group of cases which in addition to the signs and symptoms just outlined (Group 3), present signs of increased intracranial tension (headache, vomiting, choked disk superimposed on atrophy) The

lesion originating in or about the sella has given rise to an intracranial extension sufficiently large to produce general pressure and sometimes focal symptoms. Surgery in this group has chiefly attempted to relieve general pressure symptoms for it has assumed that the primary lesion is inoperable.

The four groups of cases thus far considered represent successive stages in the growth of true hypophysial lesions.

5 A group of cases in which the lesion is primarily suprasellar in origin. The lesion arises either from cell inclusions of the cranio-pharyngeal duct or from the base of the brain and causes pressure on the chiasm and hypophysis from above. There may be the neighborhood symptoms described under Group 3 and glandular symptoms due to hypophysial deficiency. The sella turcica may be normal, enlarged, flattened, partly or completely destroyed. In the later stages, there are in addition general pressure symptoms due often to an internal hydrocephalus from occlusion of the third ventricle. Surgery in this group of cases has thus far been unsuccessful.

6 A group of cases—exceedingly small—in which the lesion arises from the optic chiasm itself. Only one such case has occurred in our series, and I have been unable to find records of similar cases. They may be grouped with the suprasellar lesions, both from the standpoint of symptomatology and treatment.

Let us discuss these clinical groups from the standpoint of our operative findings in order to discover to what extent the clinical signs we have relied on actually indicate the size and extent of the lesion. We have no data on the first group, for in the presence of secretory abnormalities alone and in the absence of headache or visual disturbances we have not felt justified in resorting to surgery. In the second group of cases, it has been assumed that the absence of visual disturbances and the absence of destruction of, or alteration in, the distance relations between the clinoid processes are indications that the hypophysial lesion is confined to the sella turcica. Such, however, is not the case. We have found by an intracranial exposure that in the total absence of visual disturbances and in the absence of destruction of, or alteration in, the distance relations between the clinoid processes, hypophysial tumors have broken through the diaphragma sellae and presented moderate and even large intracranial extensions. The intracranial extensions may even appear forward between the optic nerves. Such has been found to be the case, for example, in typical acromegalics presenting no symptoms or signs other than so-called sellar headaches. In the third group which clinically present "neighborhood" symptoms and enlargement and varying grades of destruction of the sella turcica, there has invariably been a large intracranial extension of the hypophysial growth, so large, indeed, as to make the nasal approach—almost invariably used in these cases—

seem utterly futile. In the fourth group the intracranial extension is again invariable and even larger than in the third group. In the fifth group, the lesion is primarily intracranial, but here the question of differential diagnosis between hypophysial and suprasellar lesions arises. Our experience confirms the previously recognized fact that in general the *early* suprasellar lesions give rise to visual disturbances before there is much alteration in size or shape of the sella turcica. Moreover, in three of our cases particles of bone in the walls of suprasellar cysts gave rise to shadows above the sella turcica. But in the later stages of these lesions, symptoms and signs exactly like those of hypophysial lesions are the rule, and in the presence of neighborhood symptoms, glandular symptoms, and varying grades of enlargement and destruction of the sella turcica, a differential diagnosis is indeed difficult. That it cannot with any certainty be made has been our experience, that it has often not been made by others is clearly indicated from a study of the necropsy records in the literature.

Exclusive of Group 1, in which surgery at the present time is not considered indicated, every patient therefore that presents symptoms of a chiasmal lesion has in all probability an intracranial growth. The only possible exceptions are the cases falling in Group 2, and in these, while we have not a sufficient number of cases to speak positively, we know that an intracranial growth may be present.

THE ACCESSIBILITY OF CHIASMAL LESIONS

With the exception of a few dissenting views, surgical opinion thus far has been overwhelmingly to the effect that chiasmal lesions cannot be successfully attacked by an intracranial approach. Of this opinion have been those who have in largest measure contributed to our knowledge of the clinical manifestations and surgical treatment of chiasmal lesions. Their views may be thus roughly summarized:

The transsphenoidal approach will always remain the operation of choice. The intracranial route is not feasible for tumors confined to the sella turcica. It can be only palliative in the majority of cases since it does not become the operation of choice until the tumor is far advanced and since it will be impossible to remove the part of the tumor lying in the sella turcica. It fails to cope successfully with suprasellar lesions.

Our experience is at variance with these views. From the standpoint of accessibility every chiasmal lesion excepting the portions of hypophysial tumors which have extended far behind the chiasm may be exposed by an intracranial route. Tumors entirely confined to the sella turcica (rare, as we have shown) or portions of tumors within the sella turcica are easily accessible when properly approached and are susceptible of removal. Tumors which have passed beyond the confines



Fig 2—Exposure of the chiasmal region. The frontal lobe has been elevated, the temporal lobe displaced posteriorly. The brain is protected by cotton. The right optic nerve has been brought into view and appearing in front of it and between the two optic nerves is a deep red cystic tumor. The anterior cerebral artery is seen crossing the distal portion of the right optic nerve. (Drawn by Mr Brodel at operation.)



Fig 3—Drawing showing the ease with which the sella turcica, *a*, may be entered after removing the anterior extension of a hypophysial tumor, *b*, optic chiasm

of the sella are not only accessible but their size and their operability can be determined. Cysts of the hypophysis are readily accessible, for they, as the solid tumors, appear forward and are as readily susceptible of drainage or removal as by the transsphenoidal approach. Suprasellar lesions are accessible, as are the true chiasmal lesions, tumors which cannot be approached by the nasal route. From the standpoint

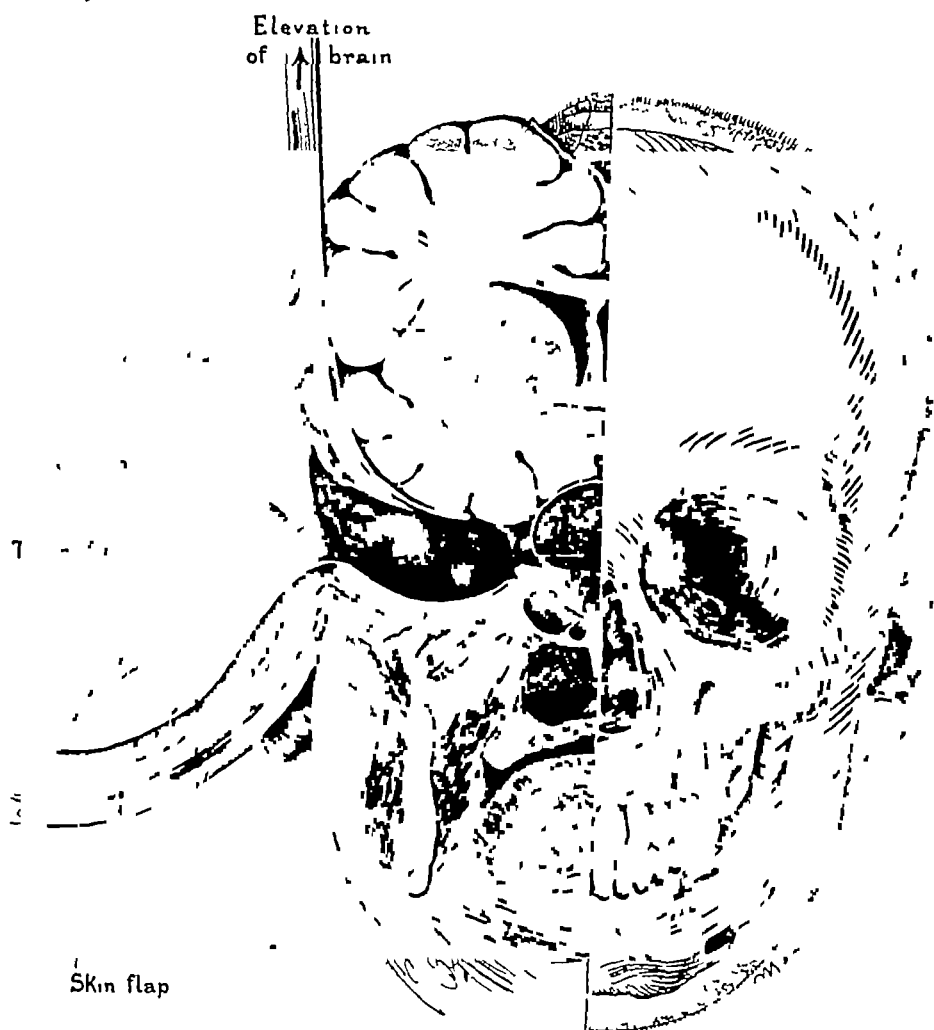


Fig 4—Semidiagrammatic sectional view of the approach to the chiasmal region. The approach is a lateral one, along the posterior border of the anterior fossa.

of accessibility, we would reverse the opinion of those just quoted and say that an intracranial approach best exposes and can most adequately deal with the greatest number of chiasmal lesions, and that the transsphenoidal approach should be considered only in those early cases—Group 2—in which there are sellar headaches but no neighborhood symptoms.

Our surgical experiences with an intracranial approach to chiasmal lesions have then been productive of the following observations

1 The proportion of suprasellar lesions to hypophysial lesions is greater than the literature would indicate and that therefore a larger number of chiasmal lesions must be approached by an intracranial route

2 The great majority of hypophysial lesions are adenomas, and of these 80 per cent are solid and 20 per cent are cystic tumors, and that probably 50 per cent of the suprasellar lesions are cysts susceptible of drainage

3 The primary direction of growth of hypophysial lesions is toward the intracranial chamber, and the intracranial extensions are primarily forward in front of the chiasm and between the optic nerves—in a direction therefore which makes them accessible by an intracranial approach

4 The absence of visual disturbances and destruction of the clinoid processes are no index that the hypophysial lesion has not broken through the sellar diaphragm and become an intracranial growth, that *with* visual disturbances and destruction of the clinoid processes the lesion is invariably an intracranial growth

5 The differential diagnosis between hypophysial and suprasellar lesions at certain stages in their growth is very uncertain

6 With the exception of the late posterior intracranial extensions of hypophysial lesions, every chiasmal lesion which presents symptoms requiring surgical relief is accessible by an intracranial approach, although, as I shall subsequently point out, not always operable

When we view the matter in the light of these observations and when we consider that the transsphenoidal approach is septic, that its exposure is limited to the size of the sellar floor, that it permits no idea of the size and extent of the lesion with which the surgeon has to deal, that it merely allows the removal of portions of a lesion remote from, rather than the portion of the tumor actually causing, the symptoms for which operation is undertaken, that it wholly fails to deal either with intracranial extensions of hypophysial tumors or suprasellar lesions, that its results have been unsatisfactory and merely palliative, can we doubt that, at the present stage of chiasmal surgery, the intracranial approach to chiasmal lesions should have a wider trial? There are good reasons, however, why it should not at the present time be indiscriminately used, for, as the following pages will indicate, its mortality for the time being is high. It has been attended by certain complications, and its results are still none too brilliant

OPERATION AND COMPLICATIONS

The operation which we have employed is adequately portrayed in the accompanying illustrations drawn by Mr Brodel and requires

little description. An osteoplastic flap is turned down over the frontoparietal region on the side presenting the greatest visual or other neighborhood symptoms. The flap should be large in order to permit more easily later cerebral dislocation. A dural flap is reflected concentric with the bone flap. Should the brain be under tension, a ventricular or lumbar puncture is performed before the base of the frontal lobe is elevated. The approach to the chiasm is neither a direct frontal nor a temporal, but midway between the two and along the posterior margin of the anterior fossa. It is the shortest approach to the chiasmal region. The posterior part of the base of the frontal lobe is elevated and the chiasm brought into view. The hypophysial lesion, if such it be, will immediately present itself. It has lifted the chiasm and come forward over the anterior margin of the sella turcica between the optic nerves. The extent of the growth and its relations to the internal carotid arteries can readily be determined. The portions of the lesion that appear, be they solid tumor or cyst, are removed, after which the sella turcica can be entered through the space between the uplifted chiasm and the anterior border of the sella. In the presence of suprasellar lesions a different picture presents itself. The optic chiasm is depressed, not elevated as in chiasmal lesions. The part of the lesion that appears is behind the chiasm, yet if it is a cyst it can be successfully attacked. In the large lesions, the downward extension may actually be seen occupying the sella turcica.

This operation has up to the present time been performed largely on patients in the late stages of chiasmal tumors. The lesions have with few exceptions been large. Our attitude toward them has been deliberately radical, and, excepting the solid suprasellar lesions which we have found thus far impossible to remove completely, we have attempted the removal of every lesion which presented itself, regardless of its size. In every case of hypophysial lesion, we have entered the sella turcica and removed partly or wholly its intrasellar portion.

The complications which we have encountered at the time of operation are these. Sufficient elevation of the brain to deal successfully with the lesion has been impossible in the case of solid suprasellar tumors only. In the course of elevation, the cortex has, of course, been compressed, but not lacerated, due to careful protection and the use of broad spatulas. As a result of this elevation the olfactory nerve has been torn out of the cribriform plate on the side of operation in two instances. Unintentional laceration of one optic nerve has occurred in one case during the attempt to remove a large hypophysial tumor. The internal carotid artery infiltrated and surrounded by tumor tissue was once completely torn across flush with its point of entrance into the intracranial chamber. The hemorrhage was successfully controlled, but only after ligation of the internal carotid in the neck. Injury to the anterior cerebral artery occurred in two instances, but in each the vessel was successfully ligated.

The postoperative complications, aside from those due presumably to hypophysial deficiency, have been largely the result of elevation of the brain. Convulsions occurring within forty-eight hours after operation occurred in three cases, twitching of the muscles of the face and hand occurred in three additional cases. Weakness of the face alone or the face and arm occurred in three cases. Speech defects occurred in two cases. These complications in those who recovered from the operation were but temporary and had disappeared usually by the end of the first week. Cerebral edema giving rise to general pressure symptoms occurred in two cases and was the primary cause of death. A sharp temperature reaction, the temperature sometimes rising to from 105 to 106 F, has been common.

Symptoms of disturbed hypophysial function have been present as follows. A stuporous lethargic condition has been present in six cases, excessive thirst in three cases, marked polyuria and polydipsia in four cases, excessive hunger in two cases. A few of our deaths, as we shall point out, occurred in patients showing signs of hypophysial deficiency, and it is possible that our extirpations have been too radical.

RESULTS

Six patients, as previously noted, were not treated. They were either the very early cases included in Group 1, stationary acromegalics in whom operation did not seem indicated, or patients that refused operation. Two patients were treated by decompression for the relief of pressure symptoms. Five patients were subjected to a trans-sphenoidal operation, and all recovered. It is in the cases in which an intracranial operation was performed that we wish especially to study the results. Thirty intracranial operations with partial or complete removal of solid tumors or with evacuation of cysts were carried out on twenty-four patients. In six of these patients, therefore, a second operation was performed from one to three years after the first. The primary mortality was 37 per cent, the total mortality from additional deaths due to second operations performed from one to three years after the primary operation was 46 per cent. When we examine into the causes of death we find. Eight of the deaths occurred within twelve hours after operation, and in these death must be ascribed directly to the operation. In three of these cases, death was due presumably to shock, in two cases it was preceded by signs of a rapidly on-coming cerebral edema. In three cases, the patients recovered consciousness and for a time were in good condition, with a not unusually rapid pulse and normal respirations. Within a few hours, however, the temperature rapidly rose to from 104 to 107 F, the pulse became rapid, the respirations increased in frequency but later decreased to as low as six per minute, stupor and unconsciousness appeared, and in this condition the patients died. Of the remaining six deaths, one

occurred on the fourth day after operation due to a repeatedly forming extradural clot, two patients died suddenly—one thirteen days after operation following straining at stool, the other fourteen days after operation, from pulmonary and cerebral embolism (confirmed at necropsy), two patients died five days after operation with all the

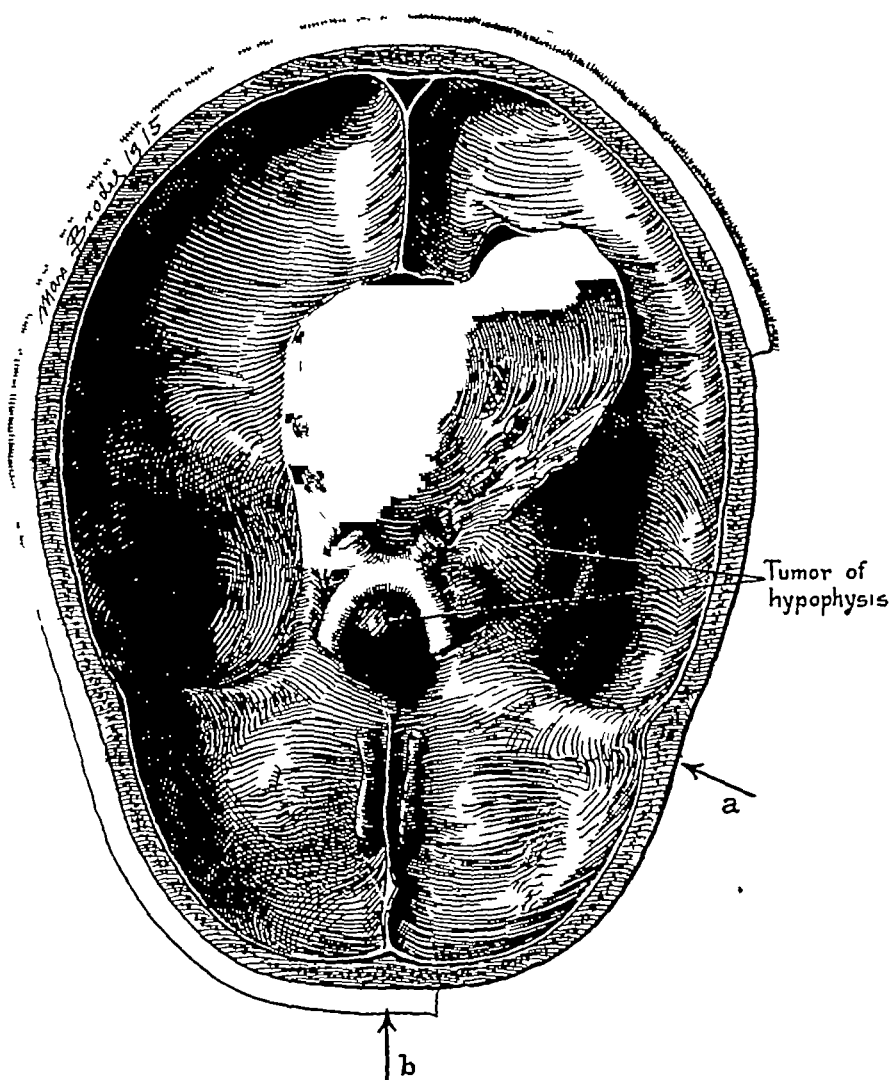


Fig 5—Drawing from a necropsy specimen showing the common anterior extension of a hypophysial tumor and also a lateral extradural extension of the growth into the temporal fossa. The approach is in the direction of the arrow at *a*. The lateral extension of the tumor in this case was accessible.

signs of hypophysial deficiency, and one patient died forty-six days after operation from internal hydrocephalus unrelieved by operation or by repeated ventricular puncture.

Of the patients who survived the primary operation, six were subjected to a second operation for a recurrence of the symptoms. One

(suprasellar cyst) had recovered her vision and was entirely free from symptoms for one and a half years, then died following the second evacuation of the cyst. One (hypophysial cyst) was free from symptoms for seven months, then had a recurrence of symptoms and died following the second evacuation of the cyst. One (adenoma of hypophysis) was free from symptoms for one year, then had a recurrence and died with symptoms of hypophysial deficiency following a second extirpation. Two (adenomas of hypophysis) who were free from symptoms for two years and one year, respectively, were subjected to second operations because of recurrence of the symptoms. Both recovered and are still free from symptoms, five years after the primary operation. One (tumor of optic chiasm) who was free from symptoms for four years, developed general pressure symptoms, due presumably to an internal hydrocephalus, and was subjected to a second operation which terminated in a decompression. This patient recovered from the second operation but has recently died. Of the remaining cases, one (suprasellar solid tumor), admitted with marked pressure symptoms for which a decompression was performed six years ago, is living and is absolutely without symptoms five years after a partial extirpation of the growth. One (hypophysial adenoma) is entirely free from symptoms three years after operation. One (hypophysial adenoma), operated on two years ago, is living but from a recent letter is apparently beginning to have a recurrence of the symptoms. One (hypophysial adenoma) died at her home four months after operation. One (suprasellar cyst), operated on four years ago, has not been heard from.

Our total results to date, therefore, in the group of cases in which an intracranial operation was performed, are three patients living and free from symptoms five years after operation, one patient living and free from symptoms three years after operation, and one patient living but with probably a recurrence of symptoms two years after operation. One patient lived quite free from symptoms for four years after operation, then died of internal hydrocephalus, the result of occlusion of the third ventricle. Three patients lived for from one to one and a half years quite free from symptoms, but died as a result of second operations performed for a recurrence of symptoms.

COMMENT

In view of what was attempted and actually done, it would be unfair to compare our mortality with that of the transsphenoidal operation. When we review the cases in which an intracranial operation was performed, we find that the large majority were late cases in which, in addition to the local symptoms of chiasmal disease, general pressure symptoms were present. A number of these patients had had transsphenoidal operations performed by other surgeons and came to us

for a recurrence of symptoms. In other words, our efforts were directed toward relieving those who were beyond help from the point of view of transsphenoidal operations, and in whom a simple decompression for the relief of pressure symptoms had been heretofore thought to be the only possible means of relief. Viewed from this standpoint our results are not quite so insignificant as would at first appear.

We may thus summarize our experiences in regard to the operability of chiasmal lesions. Chiasmal lesions are quite accessible by an intracranial approach. The cystic tumors whether hypophysial or suprasellar are, however, prone to recur, and we have not as yet been able by an intracranial approach to prevent their recurrence. The solid hypophysial tumors, excepting the rare posterior extensions, may be removed, when large, their removal has been attended by a high mortality, when small by a much lower mortality. The true lesions of the optic chiasm are so few that they need not seriously be considered. Yet they are capable of removal, and in our single case the patient lived for four years quite free from symptoms. The suprasellar solid tumors have thus far in our experience been impossible to remove completely, yet in one instance by a partial removal, we cured an internal hydrocephalus causing marked pressure symptoms, and the patient is still living and free from symptoms five years after operation.

As to the choice of operative procedures in patients who present signs of chiasmal lesion, we would suggest that both the transsphenoidal operation and an intracranial operation such as we have used have a field of usefulness. In the early cases which present sellar headaches and evidences of secretory derangement but without visual disturbances or destruction of the clinoid processes of the sella turcica, a transsphenoidal operation may well meet the requirements. A certain number of these patients may remain well for long periods, a fairly large number will sooner or later develop an intracranial extension of the growth, causing visual disturbances and destruction of the clinoid processes. Just as soon as these signs appear, the transsphenoidal approach will fail to deal adequately with the lesion, and rather than repeat this procedure it would appear wise to resort to an intracranial operation. For all other chiasmal lesions which at the time first observed are associated with visual disturbances and alterations in the shape and size of the sella turcica, the intracranial operation is the operation of choice, for in these we know that an intracranial tumor is present. It is true that our mortality following this operation is at present high, but we have reason to believe that if this operation is performed before the intracranial growths are too large, the mortality will be greatly lowered.

THE RESULTS OF OPERATIONS FOR INGUINAL HERNIA

PERFORMED IN THE JOHNS HOPKINS HOSPITAL
FROM JAN 1, 1899, TO JAN 1, 1918

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At a meeting of the Johns Hopkins Medical Society held on Nov. 4, 1889, Dr Halsted showed five patients operated on for inguinal hernia by a new method¹ Dr Halsted published several papers describing the operation during the first decade after the opening of the hospital, and in 1899, Dr Bloodgood² published a voluminous monograph, the results of a comparative study of the operations performed in 459 cases of hernia in the Johns Hopkins Hospital from June, 1889, to January, 1899 During the period of the draft board examinations, an unusually large number of men were operated on for hernia, both in the civil hospitals and in the various camps, and it seemed most opportune to study anew the material available in the records of the hospital, giving especial attention to the operations performed since the publication of Dr Bloodgood's monograph

Bloodgood's study includes a report of all the cases of hernia in which operation was performed in the hospital from its opening in 1889 to the end of 1898, a period of nine and one-half years, and is a complete report of a large series of early cases in which the modern operation was performed The conclusions drawn largely influenced the development of the present day operation He traces the development of the operation from Dr Halsted's first report in December, 1889, to the end of 1898 He calls attention to the fact that Bassini's³ paper appeared several months subsequent to Dr Halsted's report, in which the subjoined outline is given

1 The incision begins at the external abdominal ring and ends one inch or less to the inner side of the anterior superior spine of the ilium on an

1 Halsted, W S Radical Cure of Hernia, Bull Johns Hopkins Hosp 1 12, 1889

2 Bloodgood, J C Operations on 459 Cases of Hernia in the Johns Hopkins Hospital from June, 1889, to January, 1899 The Special Consideration of 268 Cases Operated on by the Halsted Method, and the Transplantation of the Rectus Muscle in Certain Cases of Inguinal Hernia in which the Conjoined Tendon is Obliterated, Johns Hopkins Hosp Rep 7 223-563, 1899

3 Bassini, E Ueber die Behandlung des Leistenbruches, Arch f klin. Chr 40 229-276, 1890

imaginary line connecting the superior spines of the ilia Throughout the entire length of the incision everything superficial to the peritoneum is cut through

2 The vas deferens, with its vessels, is carefully isolated up to the outer termination of the incision and held aside

3 The sac is opened and dissected from the tissues which envelop it

4 The abdominal cavity is closed by mattress sutures passed through the peritoneum at a higher level by $1\frac{1}{2}$ inches than that of the so-called neck of the sac.⁴

5 The vas deferens and its vessels are transplanted to the upper outer angle of the wound

6 Interrupted, strong silk sutures, passed so as to include everything between the skin and the peritoneum, are used to close the deeper portion of the wound, which is sewed from the crest of the pubes to the upper angle of the incision The cord now lies superficial to these structures, and emerges through the abdominal muscles about 1 inch to the inner side of the anterior superior spine of the ilium

7 The skin is united over the cord by interrupted stitches of very fine silk The stitches do not perforate the skin, and when tied they become buried They are taken from the under side of the skin, and are made to include only its deeper layers—the layers which are not occupied by the sebaceous follicles

The first step in the modification of the operation was described by Dr Halsted⁵ when he published accounts of several cases in which operation was performed by the modified method He described the excision of a number of the large veins of the cord by which its size could be reduced to about one fourth of the normal This was done with the object of lessening the tendency of the hernia to recur along the path of the cord

The following year, Dr Halsted⁶ published an important article in which he fully described the operation and reported eighty-two cases The next year he⁷ reported on the substitution of silver wire for silk in the closure This was because of the frequency of infection in the early years following the use of silk material in this operation The incidence of infection after the substitution of silver for silk became less The wearing of gloves quite invariably for all operations by the operator as well as by the assistants was not insisted

4 In the light of the importance of the high ligation of the neck of the sac we are now better able to appreciate the value of this feature of the operation

5 Halsted, W. S. Excision of Some of the Veins of the Cord in the Operation for the Radical Cure of Inguinal Hernia, *Bull Johns Hopkins Hosp* 3 76, 1892

6 Halsted, W. S. The Radical Cure of Inguinal Hernia in the Male, *Bull. Johns Hopkins Hosp* 4 17-24, 1893, *Ann Surg* 17 542-556, 1893

7 Halsted, W. S. Report of Twelve Cases of Complete Radical Cure of Hernia by Halsted's Method of Over Two Years' Standing Silver Wire Sutures *Bull Johns Hopkins Hosp* 5 98-99, 1894

on until about 1896, although their use, begun in 1890, became increasingly common in the intervening years

The percentage of infection being markedly reduced (18 per cent) by the systematic wearing of gloves, it was found that silver wire could be discarded and silk again employed

In 1895, Dr Halsted⁸ called attention to the occurrence of atrophy of the testicle following excision of the veins, and cautioned against the indiscriminate employment of this procedure. In 1901, and indeed in his first paper, he reported performing the operation without the transplantation of the cord, and in August, 1903,⁹ he published the account of the use of the cremaster muscle¹⁰ drawn under

8 Halsted, W S Discussion upon Hernia, *Tr Am Surg* **13** 343-344, 1895

9 Halsted, W S The Cure of the More Difficult as Well as the Simpler Inguinal Ruptures, *Bull Johns Hopkins Hosp* **14** 208-214, 1903

10 "The Use of the Cremaster Muscle A device which we hit upon in our efforts to close more securely the lower part of the canal, but which we now make use of as often as feasible, probably in over 75 per cent of the cases, is the utilization of at least a part of the cremaster muscle, which we formerly cut away This is a step of the operation to which one is irresistibly drawn in some cases by the great strength of the cremaster and the firmness and extent of its attachments to Poupart's ligament A natural insertion, such as this, of the cremaster and its fascia into Poupart's ligament, has in each case a value which can be demonstrated on the operating table and can be counted upon definitely to contribute something, and occasionally perhaps a great deal, to the strength of the abdominal wall, whereas the artificial insertion of the internal oblique into Poupart's ligament, although undoubtedly of the utmost importance and always to be tried for, may occasionally and perhaps often fail, from insufficient muscle, too great tension, or gradual redressment, to close securely even the upper part of the canal The lower part of the canal, ordinarily protected by the conjoined tendon, can rarely be entirely safeguarded by the muscle fibers of the internal oblique when its conjoined tendon is deficient The cremaster, on the other hand, seems in just these cases to serve a particularly good purpose The cremaster, unaided, has repeatedly made such a complete and strong looking closure that we have felt the hernia would be well cured if the operation were abandoned at this stage

"I have today, June 10, 1903, examined a patient whose very wide inguinal canals (the gap would have admitted the hand) were closed eighteen months ago solely by the cremasters stitched over instead of under the internal oblique muscle, the result, in the opinion of those who examined the case, is absolutely perfect, on both sides My house surgeon, Dr Follis, and one or two others examined the man with me Even had I known what the result of this case was to be, I would have used, if possible, the internal oblique muscles in the old way, and hence have stitched the cremaster under rather than over the former But the muscles were attenuated and not close at hand Stitching the cremaster over the internal oblique muscle necessarily precludes the sewing of the latter to Poupart's ligament The closure with the cremaster seems almost ideal in some cases—it is a method so inviting during the operation, and so true when finished, to one of the *great principles of surgery, there is no tension* It is, in this respect, as a plastic operation should be

the internal oblique, which constitutes an important step in the usual present day operation which I shall describe herewith in detail

In the study of the ultimate results, Bloodgood was impressed with two causes for the recurrence of the hernia, the obliteration of the conjoined tendon as the cause of the recurrence in the lower angle of the wound, and the presence of the cord in the upper angle of the wound in those cases in which it had been transplanted intact without excision of the veins

A summary of Dr Bloodgood's monograph as given by Dr Halsted⁹ is reproduced in Tables 1, 2 and 3

In the female, there were thirty-nine cases, with one recurrence through a rent in the aponeurosis

In six patients operated on by the McBurney method, there were three recurrences

Bloodgood made these observations concerning hydrocele Hydrocele occurred in about 4 per cent of the cases in which the veins had not been excised, and in 22 per cent in which they had been

THE PRESENT INVESTIGATION

The chief purposes of this investigation have been (1) to determine the cause of recurrence or weakness in the wound following the various procedures made use of in the efforts to cure hernia, and (2) to appraise the value to be attached to each of the several features of the operation

It must be evident that our objects would at the outset have been defeated had we not resolved to conquer the temptation to make the results appear as creditable as possible The natural tendency to dim

What the ultimate verdict will be it is too soon to predict The cremaster fibers, particularly the hypertrophied ones, will, in time, atrophy, but when this occurs, the cremasteric fascia, perhaps stronger than before, would probably remain, holding together the atrophied muscle bundles There can, at least, no harm result from this attempt to strengthen the wall, for the internal oblique muscle has been used in the usual manner The worst that could happen would be a recurrence, in a certain class of cases at the lower angle, one that might, possibly, have been avoided if the aponeurosis over the rectus had been employed instead of the cremaster as described by the author The future will decide these nicer points, and it would seem that only the nicer points remain now to interest the operator"

Dr Halsted tells me he has just discovered the fact that he was not the first to recognize the value of the cremaster muscle in the operation for the cure of hernia Alexander Brenner advised suturing the lower edge of the split cremaster muscle to the edge of the internal oblique in 1898 (*Zentralbl f Chir* 25 1017, 1898), Noetzel (*Zentralbl Chir* 45 352 1918) regrets the fact that Brenner's modification of the Bassini operation is practically unknown and strongly recommends it

the light on the first evidences of a possible recurrence may mislead the students and for a time the patient, but it may blind also the surgeon to the defects of his work and thus interrupt or bar his further progress

TABLE 1—SUMMARY OF THE ULTIMATE RESULTS, COMPLETE TO JUNE 1, 1899*

	Cases	Recurrences	Per Cent
All cases Group 1 to 5 healing p p	301	13	4.3
All cases Group 1 suppurating	31	9	29.0
Total	332	22	6.6
Halsted's operation, Group 1, healing p p	216	9	4.1
Halsted's operation, Group 1, suppurating	20	6	30.0
Total, Group 1	236	15	6.2

* Recent cases, less than six months, and cases lost track of were not included

TABLE 2—RECURRANCES IN WOUNDS HEALING PER PRIMAM

	Cases	Recurrences
(1) At the position of the transplanted cord, veins excised	109	None
(2) At the position of the transplanted cord, veins not excised	109	7 (6.4%)
(3) Upper angle of the wound, cord excised, or not transplanted	83	1 (1.2%)
(4) Lower angle of the wound, conjoined tendon wide and firm, rectus muscle not transplanted	264	None
(5) Lower angle of the wound, conjoined tendon obliterated, rectus muscle not transplanted	8	5 (62.0%)
(6) Lower angle of the wound, conjoined tendon obliterated, rectus muscle transplanted	14	None
(7) Lower angle of the wound, conjoined tendon wide and firm, rectus muscle transplanted	16	None

TABLE 3—RECURRENCE IN WOUNDS HEALING AFTER SUPPURATION

	Cases	Recurrences
(1) At the position of the transplanted cord, veins excised	9	None
(2) At the position of the transplanted cord, veins not excised	11	4 (36.3%)
(3) Upper angle of the wound, cord excised or not transplanted	11	1 (9.0%)
(4) Lower angle of the wound, conjoined tendon wide and firm, rectus muscle not transplanted	27	2 (7.4%)
(5) Lower angle of the wound, conjoined tendon obliterated, rectus muscle not transplanted	4	2 (50.0%)

From Jan 1, 1889, to January, 1918, there were performed in the Johns Hopkins Hospital 256 operations for *direct* and 2,230 for *indirect* inguinal hernia. In July, 1918, letters were sent to all patients treated between these dates with the request that they present themselves for examination if possible, and if unable to do so, to send a report of the local condition from their physician. The results in 910 cases have been ascertained.

Of 816 cases of indirect hernia, the results are known in 356 from examination in this hospital, and of 460 cases we have reports from physician or patient. In the group (356) examined here, thirty

recurrences were found. Of the 460 patients who responded by letter, only sixteen reported recurrence. Evidently the patients overlooked early recurrences. As the percentage of recurrence in those examined by surgeons at the Johns Hopkins Hospital is more than twice as great as in those who reported by letter, we may conclude that recurrences have been overlooked by the patients themselves or their examining physicians, and hence that the actual number of recurrences is greater than our figures indicate. The average time that had elapsed since operation in 770 cured cases was six years, and the average time after operation of forty-six recurrent cases was forty-two months.

TABLE 4—INDIRECT HERNIA

Number of operations for indirect hernia		2 230 (89.7%)
Patients examined at Johns Hopkins Hospital	350	recurrences 30 (8.4%)
Patients heard from	460	recurrences 16 (3.4%)
Total known results	816	recurrences 46 (5.6%)
Average age of patients at time of operation		39 years
Average age of the 46 patients at time of recurrence		41 years
Average time after operation of recurrence in the 46 cases		42 months

TABLE 5—RECURRENCES OF INDIRECT HERNIA—FIVE YEAR PERIODS

	Patients Examined or Heard From	Recurrences	Per Cent
1899-1904	279	26	9.3
1904-1909	137	7	5.1
1909-1914	171	11	6.4
1914-1918	229	2	0.8

TABLE 6—INDIRECT HERNIA—PATIENTS CURED

Time Elapsed Since Operation	Number of Patients	Time Elapsed Since Operation	Number of Patients
6 months	15	10 years	18
1 year	113	11 years	16
2 years	105	12 years	14
3 years	105	13 years	10
4 years	73	14 years	17
5 years	49	15 years	23
6 years	36	16 years	17
7 years	38	17 years	22
8 years	24	18 years	11
9 years	27		

Of the patients operated on for direct hernia, forty-seven were subsequently examined at this hospital and found to be cured, and thirty so reported themselves by letter. In these seventy-seven cases, the average time that had elapsed since operation was five years. By examination here, fourteen recurrences were found, and three patients reported a recurrence by letter. The average period of recurrence in these direct cases was eight and six-tenths months after operation.

In attempting to determine the factors involved in the recurrence of an inguinal rupture there have been considered the type of the hernia, the condition of the structures—especially of the conjoined tendon—the features of the operation, the healing of the wound, the age and sex of the patient, and the operator

In the course of this study a number of patients operated on previous to 1899 were incidentally seen, and the results of these examinations have been recorded in Table 7

Of the ninety-five cases in which the veins were excised, hydrocele is known to have occurred in nineteen (20 per cent)

Of 721 cases in which the veins were not excised, hydrocele occurred in twenty-eight (3.8 per cent) The correspondence of these figures with those of Dr Bloodgood (22 per cent—4 per cent) is striking

Local anesthesia was used in the indirect hernia operation fifty times—recurrence, six (12 per cent) Infection followed the use of local anesthesia in one case (no recurrence), an infected suture in this case was removed one year after operation

TABLE 7—EXAMINATION OF PATIENTS OPERATED ON PREVIOUS TO 1899

Time Elapsed Since Operation	Number of Patients	Time Elapsed Since Operation	Number of Patients
19 years	10	24 years	6
20 years	11	25 years	6
21 years	6	26 years	1
22 years	4	27 years	2
23 years	3		

Infection of the wound occurred in eight cases—recurrences, two (25 per cent)

Cases of indirect hernia with more or less completely obliterated conjoined tendon, forty-eight—recurrences, eighteen (37.5 per cent.) This is a greater percentage of recurrence than in those cases of the direct variety in which the conjoined tendon was not obliterated In these forty-eight cases of weak or partially obliterated conjoined tendon, the cord was transplanted eight times—recurrences, two (25 per cent) In one of these recurrent cases, the recurrence was found at the lower angle of the wound, in the other case, the patient was not seen subsequent to the operation, the recurrence was reported by letter and its exact situation is unknown

The rectus muscle was transplanted in twenty-two cases—recurrences, nine (40.9 per cent)

A flap from the rectus fascia was transplanted in thirteen cases—recurrences, none

The cord was transplanted in nineteen cases—recurrences, 7 (36.8 per cent). The recurrence was found at the site of the transplanted cord in three cases, at the lower angle of the wound in one, and in three the position of the recurrence is unknown.

The cord was split, the veins alone transplanted in forty-four cases—recurrences, 8 (18.1 per cent). In six of these cases the recurrence was found at the site of the transplanted veins, and in two at the site, as well, of the untransplanted vas deferens. Thus the splitting of the cord does not seem to have reduced the percentage of recurrence but to have transferred the site of the recurrence.

TABLE 8—INDIRECT HERNIA—RECURRANCES—RESULTS OF THE INDIVIDUAL OPERATOR

Operator	Patients Examined or Heard From	Recurrences	Per Cent
A	7	2	28.5
B	62	15	24.1
O	28	1	3.5
D	57	1	1.7
E	23	0	0.0
F	66	2	3.0
G	78	6	7.6
H	11	2	18.1
I	59	1	1.6
J	60	2	3.3
K	27	1	3.7
L	70	2	2.8
M	57	4	7.0
N	22	0	0.0
O	41	1	2.4
P	36	1	2.7
Q	18	1	5.5
Miscellaneous	94	4	4.2
Total	816	48	5.6

TABLE 9—OPERATIVE DETAILS OF THE FORTY-SIX RECURRENT CASES

Local anesthesia used	6
Infection	2
Cord transplanted	7
More or less completely obliterated conjoined tendon	18
Veins excised	13
Rectus muscle transplanted	9
Cremaster drawn under internal oblique	13
Cord split, veins alone transplanted	8
Recurrence at site of transplanted veins	6

The cord was excised in twenty-one cases—recurrences, none.

There was an undescended testicle with indirect hernia in nine cases—recurrence, 1 (11.1 per cent). In the recurrent case the testicle had been replaced in the scrotum. In the other eight cases, castration had been performed in four instances, and the testicle had been replaced in the scrotum in four.

There was a strangulated indirect hernia in eleven cases (two drained)—recurrence in both of the drained cases. In the nine undrained cases—recurrence, none.

Of eighty-seven cases in which the veins were not excised, hydrocele occurred in two (2.2 per cent), whereas in the nine treated by excision of the veins it occurred in seven (77.7 per cent).

Local anesthesia was used in operations for direct hernia eleven times—recurrences, two (18.1 per cent).

TABLE 10—DIRECT HERNIA

Number of operations for direct hernia		256 (10.2%)
Patients examined at Johns Hopkins Hospital	47	recurrences 14 (29.7%)
Patients heard from	47	recurrences 3 (6.3%)
Total known results	94	recurrences 17 (18.08%)
Average age of patients at time of operation		42 years
Average age of the 17 patients at time of recurrence		44 years
Average time after operation of recurrence in the 17 cases		8.6 months

TABLE 11—RECURRENTS OF DIRECT HERNIA—FIVE YEAR PERIODS

	Patients Examined or Heard From	Recurrences	Per Cent
1899-1904	16	4	25.0
1904-1909	16	2	12.5
1909-1913	35	8	22.8
1914-1918	27	3	11.1

TABLE 12—DIRECT HERNIA—PATIENTS CURED

Time Elapsed Since Operations	No. of Patients
1 year	15
2 years	11
3 years	16
4 years	8
5 years	4
6 years	4
7 years	4
8 years	1
9 years	10
10 years	1
11 years	1
12 years	1
13 years	1

Infection occurred in four cases—recurrences, two (50 per cent). In one of the recurrent cases local anesthesia was used.

Of direct hernia with more or less completely obliterated conjoint tendon there were nineteen cases—recurrences, six (31.5 per cent). This is approximately the same percentage of recurrences as that found in the indirect variety with obliterated conjoint tendon. In these nineteen cases of weak or partially obliterated conjoint tendon, the

cord was transplanted nine times ~~with three~~ recurrences (33 3 per cent) The recurrence was found at the inner angle of the wound in one instance, in two its site is unknown

The rectus muscle was transplanted in twelve cases—recurrences, three (25 per cent)

A flap from the rectus fascia was transplanted in three cases—recurrence in one (33 3 per cent)

The cord was transplanted in twenty cases—recurrences, five (25 per cent) The recurrence was found both at the site of the transplanted cord and at the inner angle of the wound in one case, in one at the inner angle of the wound, and in three the site of the recurrence cannot be determined from the reports sent by letter

TABLE 13—DIRECT HERNIA, RECURRENCES—RESULTS OF THE
INDIVIDUAL OPERATOR

Operator	Patients Examined or Heard From	Recurrences	Per Cent
A	1	0	0 0
B	1	1	100 0
C	8	3	37 5
D	8	2	25 0
E	2	0	0 0
F	5	0	0 0
G	12	2	16 6
H	0	0	0 0
I	7	0	0 0
J	10	3	30 0
K	5	1	20 0
L	6	2	33 3
M	8	1	12 5
N	4	1	25 0
O	2	0	0 0
P	7	0	0 0
Q	1	0	0 0
Miscellaneous	7	1	14 2
Total	94	17	18 08

The cord was split and the veins transplanted in three cases—recurrence, none

The cord was excised in four cases—recurrence, none

MORTALITY

In the 2,486 operations performed since 1899 there have been nineteen deaths in the hospital Seven of these were due to strangulated hernia, four to pulmonary embolism, one to myocarditis, two to meningitis, four to pneumonia, one, in an infant aged 17 months, to status lymphaticus The total mortality was 0 76 per cent Excluding the deaths due to strangulated hernia, it was 0 48 per cent

TECHNIC OF OPERATION

A brief outline of the development of the operation at Johns Hopkins Hospital has been given above. The operation almost invariably performed at present is the one described by Dr. Halsted and beautifully illustrated by Max Brodel in 1903. No modification has been made in it since the publication of this paper.

The skin incision begins as a rule from a point a finger's breadth medial to the anterior superior spine and runs obliquely downward to the external ring, ending at a point one finger's breadth lateral to the pubic spine. The fat and superficial fascia are incised and the aponeurosis of the external oblique muscle split in the line of its fibers. The two columns of the external ring are then dissected back and the conjoined tendon well exposed.

TABLE 14—OPERATIVE DETAILS OF THE SEVENTEEN RECURRENT CASES

Local anesthesia used	2
Infection (1 after local anesthesia)	2
Cord transplanted	5
More or less completely obliterated conjoined tendon	6
Veins excised	2
Rectus muscle transplanted	3
Flap from rectus fascia transplanted	1
Free transplant from fascia lata	2
Cremaster drawn under internal oblique	8

TABLE 15—COMPLICATIONS FOLLOWING THE NINE HUNDRED AND TEN OPERATIONS FOR INGUINAL HERNIA

	Cases	Per Cent
Pain following operation, reported in	138	15.2
Enlarged or painful testicle, reported in	56	6.1
Loss of sexual power, veins not excised	5	0.5
Hydrocele, reported in	56	6.1
Varicocele, reported in	14	1.5
Atrophy of testicle, reported in	23	2.5
Infection in the 910 cases	12	1.2

The iliohypogastric nerve usually courses too high to be endangered, the ilioinguinal is isolated and may be held out of the way over a clamp on the upper cut edge of the aponeurosis.

The cremasteric muscle is then incised longitudinally. The sac is opened and carefully and cleanly isolated on a finger placed within it. Sharp dissection is preferred to the rubbing with gauze as thus less trauma is likely to be caused to the structures of the cord.

The sac is dissected up to the highest possible point, its contents having been reduced. The neck of the sac is twisted, transfixed and tied with silk, Size C. Having been again inspected from within, the sac is cut away quite close to the ligature about its neck, the stump usually retracts well behind the edge of the internal oblique muscle.

Hemostasis must be perfect The ligatures are of very fine black silk, Size A or O

The closure is accomplished by utilizing the cremasteric fascia and muscles in the following way Mattress sutures of silk are passed from above downward through the conjoined tendon and the internal oblique muscle in such a way that the cremaster muscle and fascia are drawn, without any tension, up under the edge of the conjoined tendon and internal oblique muscle, the knots of the mattress sutures being tied on the outer face of the muscle and tendon (Fig 1)

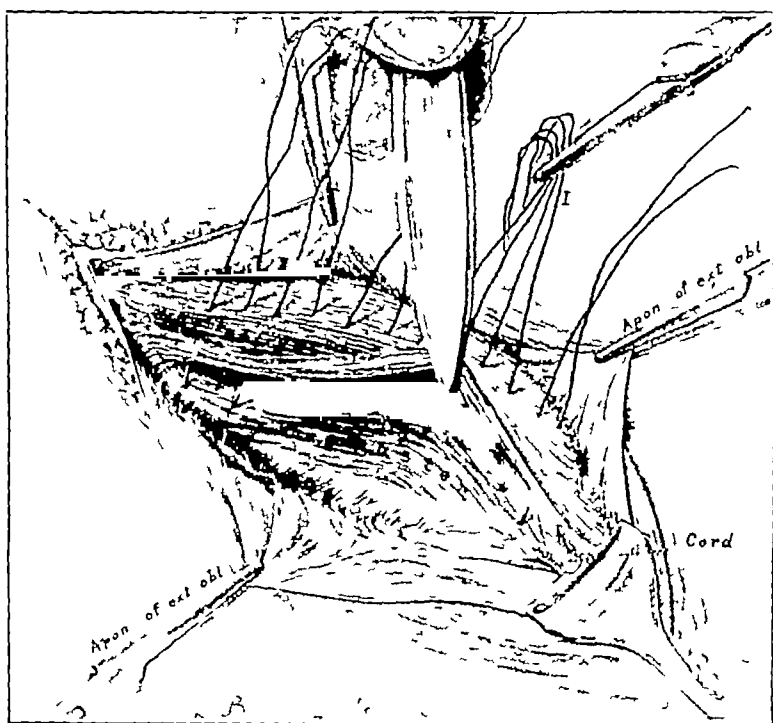


Fig 1—Use of the cremaster muscle. Drawing by Max Brodel

The cord is not disturbed The edges of the conjoined tendon and internal oblique muscle are then sutured to Poupart's ligament, if this can be done without tension, with interrupted sutures of black silk, the cord being closely embraced by these structures at the inner angle of the wound

The flaps of the aponeurosis of the external oblique muscle are overlapped, the edge of the lower flap is tacked to the outer face of the conjoined tendon and the internal oblique and then the upper flap is brought down as an overlap and sutured at its edge to the underlying aponeurosis The sutures throughout this procedure are interrupted and of fine black silk The overlapped aponeurotic flaps also hug the cord quite snugly

The superficial fascia and the skin are closed with interrupted sutures of fine silk. A small gauze dressing is held in place with a few straps of adhesive plaster. The patient is allowed to get up about the tenth day when the hernia is a simple indirect one, but may be kept in bed for three weeks in the more difficult cases of direct hernia.

In direct hernias the cord is sometimes transplanted, and if the conjoined tendon is thinned or narrow, a flap from the anterior sheath of the rectus is used after the manner described by Dr Halsted⁹ (Fig 2). The illustrations are reproduced from Dr Halsted's paper

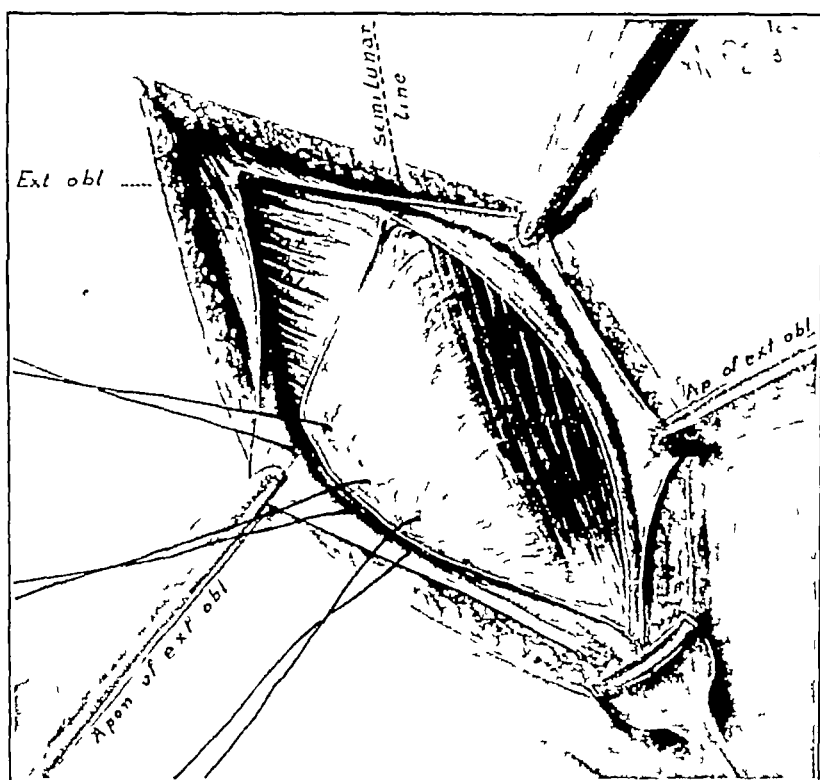


Fig 2—Transplantation of triangular flap from anterior sheath of rectus muscle. Drawing by Max Brodel.

REVIEW

The operation for uncomplicated hernia being a simple one, it is frequently entrusted to the younger members of the staff. We might expect that the higher percentage of recurrence would be found in the work of the relatively immature operators, but this proves not to be the case. The resident surgeons who have implicitly observed the details specified by Dr Halsted have, as a rule, had the fewest recurrences, while Dr Halsted himself has had slightly better results than any except those whose cases have been few, notwithstanding the fact that most of his patients were operated on many years ago.

We have examined or heard from sixty-six patients operated on by Dr Halsted since 1899, seven with direct and fifty-nine with indirect hernia, and among these no recurrence has been found by us and only one reported. As the veins were excised in this case, recurrence is thought to be uncertain, particularly as it is not improbable that a hydrocele which developed while the patient was still in the hospital after the operation may have been mistaken for it.¹¹ His percentage of recurrence is therefore 1.5 or perhaps none.

Conclusions as to the relative value of the various details of the operation are difficult to draw from data furnished by so many operators and recorders. The histories as a rule were found to be creditably complete. In the ordinary indirect hernias, the best results have been obtained by those who performed the operation strictly as described above—cord untransplanted, cremaster sutured to the undersurface of the internal oblique muscle, flap of rectus sheath made use of when indicated.

TABLE 16—DISPOSITION OF THE CORD

INDIRECT HERNIA			
Cord transplanted	19	recurrences	7 (36.8%)
Cord not transplanted	732	recurrences	81 (4.2%)
Cord excised	21	recurrences	0
Cord split, veins alone transplanted	44	recurrences	8 (18.1%)
DIRECT HERNIA			
Cord transplanted	20	recurrences	5 (25%)
Cord not transplanted	68	recurrences	12 (17.6%)
Cord excised	8	recurrences	0
Cord split, veins alone transplanted	3	recurrences	0

In both types of hernia, when the conjoint tendon was pronounced to be lacking, the percentage of recurrence is found to be exceedingly high (35.8),¹² the best results in such cases have been obtained when a flap of the sheath of the rectus muscle has been made use of. There has been only one recurrence in this little group of cases, notwithstanding the fact that this operative detail (transplantation of the rectus sheath) has been resorted to only when the conjoint tendon has been defective, and it has occasionally been practiced by operators who had not familiarized themselves with the proper method of employing it. The transplantation of the rectus muscle seems to have availed nothing. In the thirty-four cases in which it has been tested, there have been twelve recurrences (35.3 per cent). Dr Halsted has never advocated the employment of this feature, maintaining that

¹¹ In several instances reported recurrences have proved to be hydroceles.

¹² Dr Bloodgood directed attention to this fact in his first paper and has emphasized it in recent publications.

TABLE 17—RECURRENCES OF INDIRECT HERNIA

Surg No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
8479 ♂ 33 G	Jan 4, 1899 Ether Conjoined tendon wide and firm Muscles strong Sae tied with silk Cord transplanted intact Rectus muscle not transplanted Closure with silver Healing per primam No epididymitis	Recurrence noticed in 5 months Jan 15 1899, second operation, "G" Recurrence found between vas and veins Veins excised Silver sutures Healing per primam Second recurrence 5 years later at site of cord New hernia on opposite side Third operation, Jan 3, 1906, "G" Silver removed silk used Cremaster found puckered between oblique and Poupart's Ordinary operation not performed because of excessive scar tissue formation and obliteration of normal anatomic relations Ultimate result unknown
8485 ♂ 34 B	Jan 5, 1899 Ether Conjoined tendon obliterated Tissues adherent from old inflammation Sae closed high with silk Cord transplanted intact Rectus muscle sutured to Poupart's Healing per primam	July 1918 Letter from patient, "Recurrence in about 4 months after operation" This patient has not been seen subsequent to operation
8489 ♂ 18 B	Jan 5, 1899 Ether Conjoined tendon well developed Internal oblique strong No sac found Cord transplanted intact Silver sutures the lowest one through rectus muscle near spine sheath not opened Healing per primam	April, 1901 Letter from patient, "Time and money thrown away" July, 1918 Letter, "Conditions same as before operation Wearing truss"
8525 ♂ 23 B	Jan 23, 1899 Ether Very large ring Conjoined tendon strong Sae very adherent to vein and cord and difficult to remove Veins excised and cord transplanted Bassini closure used Hypospadias and undescended testicle on left where there was no hernia	Recurrence in 2 years and 4 months May 23 1901 second operation "L" Recurrence found at point of exit of vas Divided internal oblique existed as a mass of scar tissue Rectus muscle sutured to Poupart's over cord which was brought down close to pubic spine Ultimate result unknown
8548 ♂ 28 B	Jan 21 1899 Ether Conjoined tendon and other structures strong Sae ligated with purse string suture Veins excised Cord transplanted Wound closed with 5 buried silver sutures, rectus included No suture nearest symphysis Cord transplanted so high that testicle was drawn slightly above its original level Slight hydrocele followed	May, 1901 Letter from patient, "Testicle three times its size—you can see that the hernia is coming down again" July 1918 Letter, "Have worn a truss since operation Swelling below cut, size of pigeon's egg"
8608 ♂, 23 B	Feb 4 1899 Ether Conjoined tendon very narrow Muscle fibers strong Cord split, veins alone transplanted Rectus muscle sutured over vas to Poupart's Very vascular case Healing per primam	Recurrence in about 1 year at upper angle of wound at site of transplanted veins, also slight recurrence at external ring, making an hour glass sac May 27, 1903 second operation, "F" Veins excised Cremaster sutured under internal oblique Position rectus muscle not stated Operation difficult on account of scar tissue and disturbance anatomic relations Small drain July 1918 Examination here showed perfect result
8634 ♂ 23 Misc	Feb 6, 1899 Ether Conjoined tendon strong and broad Congenital type of sac Lower part of sac ligated and left in scrotum Cord transplanted Lowest sutures included edge of rectus Healing per primam	July, 1918 Letter from patient's physician "Recurrence at site of cord, one year after operation New hernia on left"

* ♂ represents male

TABLE 17—RECURRENCES OF INDIRECT HERNIA—CONTINUED

Surg No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
5663 ♂, 51 A	Feb 21 1899 Ether Conjoined tendon strong Veins excised Cord not transplanted Healing per primam Slight swelling right cord and testicle, apparently due to small hydrocele in 1 month	Recurrence in 2 years and 8 months Oct 30 1901 second operation "B" Recurrence found as new hernia between rectus and deep epigastric, pushing conjoined tendon in front Internal oblique had pulled away from Poupart's Adherent to sac at its lower end was a large mass of edematous scar tissue in the center of which, stump of ligated veins These evidently were ligated too low at first operation They were religated Vas deferens ligated Cord excised and rectus muscle transplanted No subsequent report
8865 ♂, 24 G	April 21, 1899 Ether Conjoined tendon very strong Internal oblique fair Cord split and veins alone transplanted Femoral ring large extra silver suture to pucker and decrease this Strong closure Took anesthesia badly Healing per primam	Recurrence in 1 1/4 years May 12 1912, second operation, "J" Recurrence found at site of transplanted veins These veins were excised and vas allowed to fall back behind the internal oblique close to the spine Cremaster not definitely recognized Has double varicocele July 1918 Letter from patient, "I am completely cured"
8866 ♂, 48 B	April 22 1899 Ether Very large irreducible hernia Conjoined tendon narrow and weak Internal oblique rather large and strong Cord not transplanted Closure satisfactory except at lowest angle where rectus muscle was sutured to Poupart's over cord Silver mattress sutures Infection after operation, lower half of wound widely opened	Recurrence in about 4 months Aug 4, 1899, second operation, "B" Recurrence found at lowest angle of wound Internal oblique and transplanted rectus not positively identified Cord isolated and excised with testicle. Rectus muscle exposed and included in all except lowest sutures Healing per primam No subsequent report
8894 ♂, 47 B	May 8 1899 Ether Double hernia Conjoined tendons thin Aponeurosis of external oblique thin, internal oblique and rectus strong on both sides Right side cord split, veins alone transplanted Rectus sutured to Poupart's over vas Left side no sac Large bundle veins excised Vas not disturbed Closure as on right with transplantation of rectus and internal oblique Hydrocele excised on left in March, 1902	Recurrence on right side 2 years after operation, on left, 10 years March, 1918 Examination by Dr Halsted Recurrence at each external ring, also small recurrence at site of new ring made by transplanted veins on right On account of complications operation not advised (two recurrences)
9342 ♂, 21 B	Aug 26, 1899 Cocain Conjoined tendon not palpable Other structures not described Veins alone transplanted Very satisfactory closure Healing per primam	Recurred in 18 years September 1918 Examination on admission to hospital Definite recurrence above center of Poupart's 2 1/2 by 4 cm in size at site of transplanted veins Refused operation and was discharged at his own request
9396 ♂, 42 B	Sept 12, 1899 Ether Conjoined tendon not felt. Pillars strong Internal oblique strong Veins very large, not excised Cord not transplanted Rectus muscle sutured to Poupart's over cord Closure satisfactory Healing per primam	January 1900 Examination Recurrence at lower angle of wound No subsequent report
9147 ♂, 53 B	Sept 26 1899 Cocain Conjoined tendon obliterated Muscle fibers thin Neck of sac very large closure with difficulty Veins very large, excised Vas not transplanted Rectus muscle sutured to Poupart's over vas Hernia of sliding variety Hydrocele occurred within a month Excised	Recurrence in 2 years after operation March 1902. Examination hernia now size of a large egg Operation advised (no note as to its site) No subsequent report

* ♂ represents male

TABLE 17—RECURRENTS OF INDIRECT HERNIA—CONTINUED

Surg. No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
9928 ♂, 37 B	Jan 25, 1900 Ether Conjoined tendon very weak Hernia size of ostrich egg Veins excised Vas transplanted Rectus sutured to Poupart's Silver sutures Healing per primam Large hematoma formed in wound	Recurred in about 5 years Jan 11, 1905 second operation, "I" Recurrence found at lower angle of wound Muscles and conjoined tendon weak Anterior sheath of rectus reinforced this inner portion of wound flap being turned down and sutured beneath Poupart's, after tissue corresponding to cremaster had been sutured beneath edge of internal oblique—in front of vas and its remaining vessels No subsequent report
9948 ♂, 20 I	Feb 3, 1900 Ether Conjoined tendon rather weak Veins excised Vas not disturbed Muscles closed with silver lowest suture did not include conjoined tendon Healing per primam Very slight hydrocele on discharge	April, 1903 Letter from patient's father, "Hernia apparently recurred Complaints of much pain and of hernia coming down after lifting" Reported recurrence probably a hydrocele Repeated letter to patient unanswered
10069 ♂, 45 B	March 6, 1900 Cocain Muscles so fat nerves could not be identified A double sac found Veins excised Cord not transplanted Rectus sutured to Poupart's Note by operator "One of the most difficult cases I have encountered Rings were concentric and the double sac made it very puzzling Abdominal walls fat and thick Four fingers could be inserted into the external ring"	April, 1903 Examination. Recurrence along whole wound Patient is not conscious of recurrence Small hydrocele?
10076 ♂, 45 B	April 10, 1900 Ether Condition of conjoined tendon not mentioned Pillars firm Dissection of sac difficult on account of adhesions Veins transplanted Vas left in old bed Closure with silver Healing per primam	April, 1901 Examination by Dr Halsted No recurrence April, 1903 Examination bulging at site of transplanted veins Recorded as definite recurrence March 1920 Examination by Dr Reid "Slight recurrence at site of transplanted veins Does not come through pillar"
10286 ♂, 31 B	April 25, 1900 Ether Conjoined tendon wide and firm Small split in internal oblique Sac ligated with silk Cord split, veins alone transplanted Healing per primam	Recurred in 8 years November, 1909 Operated on for recurrence by Dr Mitchell of Washington This recurrence took place at the external ring, after heavy lifting July, 1918 Letter from patient, "No trouble since operation in 1909"
10338 ♂, 27 G	May 4, 1900 Ether Conjoined tendon poor Lower part of sac very dark and congested Cord split Veins alone transplanted Hydrocele sac evacuated Silver sutures Healing per primam	July 1900 Letter from patient, "Hernia cured—swollen cord on left" July, 1918 Letter, "In 1913, a very slight return of rupture" Physician's statement, "Patient has left inguinal hernia 1½ by 2 in Rupture seems above external ring"
10570 ♂, 18 L	July 7, 1900 Ether Conjoined tendon good Sac ligated with silk Veins large, excised Vas not transplanted Healing per primam	June, 1901 Complete recurrence reported by army surgeon Subsequent letters returned

* ♂ represents male

TABLE 17—RECURRENTS OF INDIRECT HERNIA—CONTINUED

Surg No , Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
10585 ♂, 42 A	July 7, 1900 Ether Conjoined tendon wide and firm Sac contained omentum and intestine Cord split Veins alone transplanted Good closure Healing per primam Considerable swelling of cord	Recurrence noticed in about 2 months July 19, 1901 second operation 'A' Recurrence about 6 cm in diameter, along lower half of scar Veins left in transplanted position Sac not opened Wound closed by bringing rectus muscle down to Poupart's over mass of subperitoneal fat Silver sutures Recurring again in 15 years beneath transplanted rectus July 21, 1916, third operation 'D' Portion of rectus transplanted at second operation formed a dense band beneath which lay hernial sac. Poupart's very thin, only a few filaments, hence fascia from leg was transplanted March 1918 Examination by Dr Reid 'There is no recurrence There is a hard lump just at the external ring on left which seems to be indurated tissue'
10660 ♂, 25 L	July 23 1900 Ether Conjoined tendon good Veins excised Vasc accidentally cut sutured and left in position Muscles closed with silver Healing per primam	April, 1901 Examination small recurrence at lower angle with hydrocele January, 1907 Examination definite recurrence at lower angle Hydrocele, very small
13445 ♂, 25 F	June 3 1902 Cocain Conjoined tendon poorly developed but firm Cremasteric reflex absent Sac ligated with silk Veins large excised Vasc not transplanted Triangular silver sutures bringing internal oblique and conjoined tendon to Poupart's Aponeurosis overlapped with fine silk, interrupted Healing per primam	July, 1918 Examination recurrence Large hydrocele on operated side
14630 ♂, 33 F	April 30 1903 Ether Conjoined tendon fair Aponeurosis along Poupart's ligament rather weak Neck of sac sutured with fine silk and transplanted beneath edge of internal oblique Cord not transplanted Cremaster sutured to internal oblique Oatgut sutures Wound healed per primam	Recurrence in 10 years Aug 8 1914 second operation, 'F' Recurrence found at inner angle Conjoined tendon weak Large veins excised Internal oblique sutured to Poupart's including a small layer of cremaster Flap of rectus fascia reflected and sutured to Poupart's Varicocele present, also new hernia on opposite side July, 1918 Examination no recurrence Hydrocele size of Bartlett pear
16859 ♂ 27 G	Oct 21 1904 Ether Conjoined tendon fair Other structures fairly well developed Cremaster thin Previous operation 3 months before on opposite side Cord not transplanted First sutures of heavy black silk through internal oblique and cremaster both sides, conjoined tendon included in last suture Healing per primam	Recurrence in 8 years Jan 31 1913, second operation 'J' Recurrence found at lower inner angle of wound strangulated Cremaster sutured under internal oblique No subsequent report
18513 ♂ 52 P	Nov 29, 1905 Cocain Internal oblique and conjoined tendon poor Sliding hernia Closure of sac difficult and unsatisfactory Cord not transplanted Cremaster drawn under internal oblique Healing per primam	Recurrence in 15 months May 15 1907 second operation, 'P' Recurrence at lower angle of wound, strangulated Veins excised Usual closure No subsequent report

♂ represents male

TABLE 17—RECURRENTS OF INDIRECT HERNIA—CONTINUED

Surg No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
9928 ♂, 37 B	Jan 25, 1900 Ether Conjoined tendon very weak Hernia size of ostrich egg Veins excised Vas transplanted Rectus sutured to Poupart's Silver sutures Healing per primam Large hematoma formed in wound	Recurred in about 5 years Jan 11, 1905, second operation, "I" Recurrence found at lower angle of wound Muscles and conjoined tendon weak Anterior sheath of rectus reinforced this inner portion of wound, flap being turned down and sutured beneath Poupart's, after tissue corresponding to cremaster had been sutured beneath edge of internal oblique—in front of vas and its remaining vessels No subsequent report
9948 ♂, 20 I	Feb 3, 1900 Ether Conjoined tendon rather weak Veins excised Vas not disturbed Muscles closed with silver lowest suture did not include conjoined tendon Healing per primam Very slight hydrocele on discharge	April 1903 Letter from patient's father, "Hernia apparently recurred Complaints of much pain and of hernia coming down after lifting" Reported recurrence probably a hydrocele Repeated letter to patient unanswered
10069 ♂, 45 B	March 6, 1900 Cocain Muscles so fat nerves could not be identified A double sac found Veins excised Cord not transplanted Rectus sutured to Poupart's Note by operator "One of the most difficult cases I have encountered Rings were concentric and the double sac made it very puzzling Abdominal walls fat and thick Four fingers could be inserted into the external ring"	April, 1903 Examination Recurrence along whole wound Patient is not conscious of recurrence Small hydrocele?
10076 ♂, 45 B	April 10, 1900 Ether Condition of conjoined tendon not mentioned Pillars firm Dissection of sac difficult on account of adhesions Veins transplanted Vas left in old bed Closure with silver Healing per primam	April, 1901 Examination by Dr Halsted No recurrence April, 1903 Examination bulging at site of transplanted veins Recorded as definite recurrence March 1920 Examination by Dr Reid Slight recurrence at site of transplanted veins Does not come through pillar"
10286 ♂, 31 B	April 25, 1900 Ether Conjoined tendon wide and firm Small split in internal oblique Sac ligated with silk Cord split, veins alone transplanted Healing per primam	Recurred in 8 years November, 1909 Operated on for recurrence by Dr Mitchell of Washington This recurrence took place at the external ring, after heavy lifting July, 1918 Letter from patient, "No trouble since operation in 1909"
10338 ♂, 27 G	May 4, 1900 Ether Conjoined tendon poor Lower part of sac very dark and congested Cord split Veins alone transplanted Hydrocele sac evacuated Silver sutures Healing per primam	July, 1900 Letter from patient, "Hernia cured—swollen cord on left" July, 1918 Letter, "In 1913, a very slight return of rupture" Physician's statement, "Patient has left inguinal hernia 1½ by 2 in Rupture seems above external ring"
10370 ♂, 18 L	July 7, 1900 Ether Conjoined tendon good Sac ligated with silk Veins large, excised Vas not transplanted Healing per primam	June, 1901 Complete recurrence reported by army surgeon Subsequent letters returned

* ♂ represents male

TABLE 17—RECURRENCES OF INDIRECT HERNIA—CONTINUED

Surg No., Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
10585 ♂, 42 A	July 7, 1900 Ether Conjoined tendon wide and firm Sac contained omentum and intestine Cord split Veins alone transplanted Good closure Healing per primam Considerable swelling of cord	Recurrence noticed in about 2 months July 19 1901 second operation, 'A' Recurrence about 6 cm in diameter along lower half of scar Veins left in transplanted position Sac not opened Wound closed by bringing rectus muscle down to Poupart's over mass of subperitoneal fat Silver sutures Recurred again in 15 years beneath transplanted rectus July 21, 1916 third operation, 'D' Portion of rectus transplanted at second operation formed a dense band beneath which lay hernial sac Poupart's very thin only a few filaments hence fascia from leg was transplanted March 1918 Examination by Dr Reid 'There is no recurrence There is a hard lump just at the external ring on left which seems to be indurated tissue.'
10660 ♂, 25 L	July 23 1900 Ether Conjoined tendon good Veins excised Vas aesthetically cut, sutured and left in position Muscles closed with silver Healing per primam	April 1901 Examination small recurrence at lower angle, with hydrocele January 1907 Examination definite recurrence at lower angle Hydrocele very small
13445 ♂, 25 F	June 3 1902 Cocain Conjoined tendon poorly developed but firm Cremasteric reflex absent Sac ligated with silk Veins large excised Vas not transplanted Triangular silver sutures bringing internal oblique and conjoined tendon to Poupart's Aponeurosis overlapped with fine silk, interrupted Healing per primam	July, 1918 Examination recurrence Large hydrocele on operated side
14630 ♂, 33 F	April 30, 1903 Ether Conjoined tendon fair Aponeurosis along Poupart's ligament rather weak Neck of sac sutured with fine silk and transplanted beneath edge of internal oblique Cord not transplanted Cremaster sutured to internal oblique Catgut sutures Wound healed per primam	Recurrence in 10 years Aug 8 1914, second operation 'T' Recurrence found at inner angle Conjoined tendon weak Large veins excised Internal oblique sutured to Poupart's including a small layer of cremaster Flap of rectus fascia reflected and sutured to Poupart's Varicocele present, also new hernia on opposite side July, 1918 Examination no recurrence Hydrocele size of Bartlett pear
16859 ♂, 27 G	Oct 21, 1904 Ether Conjoined tendon fair Other structures fairly well developed Cremaster thin Previous operation 3 months before on opposite side Cord not transplanted First sutures of heavy black silk through internal oblique and cremaster both sides conjoined tendon included in last suture Healing per primam	Recurrence in 8 years Jan 31 1913, second operation 'J' Recurrence found at lower inner angle of wound strangulated Cremaster sutured under internal oblique No subsequent report
18413 ♂, 52 P	Nov 29 1905 Cocain Internal oblique and conjoined tendon poor Sliding hernia Closure of sac difficult and unsatisfactory Cord not transplanted Cremaster drawn under internal oblique Healing per primam	Recurrence in 15 months May 15, 1907, second operation 'P' Recurrence at lower angle of wound, strangulated Veins excised Usual closure No subsequent report

* ♂ represents male

TABLE 17—RECURRENTS OF INDIRECT HERNIA—CONTINUED

Surg No, Sex,* Age Operator	Details of Operation	Evidence of Recurrence
18917 ♂, 46 G	March 26, 1906 Ether Double hernia Conjoined tendons obliterated In ternal obliques almost like tissue paper Cremasters well developed Right side cord not transplanted silk sutures through internal oblique and Poupart's including cremaster Left side cord not transplanted same closure as on right Healing per primam	July, 1918 Letter from patient "Left side recurred 6 years after operation, repaired by naval surgeon Small recurrence on right of 1 year's standing" Two recurrences
19033 ♂, 28 Q	April 18, 1906 Ether All structures, especially conjoined tendon, poorly developed Cord not transplanted Approximation internal oblique to Poupart's formed a layer so thin as to raise doubt as to its effectiveness in preventing a recurrence Healing per primam	July, 1918 Letter from patient, "Rupture came back on right side 6 years ago, and since that have worn a support, have always felt a weakness at the point of operation Operation never successful"
21565 ♂, 58 K	Nov 12, 1907 Cocain Conjoined tendon fair Strangulated hernia High ligation of sac, its pedicle being inset under internal oblique after Kocher's method Cord not transplanted Cremaster drawn under internal oblique Healing per primam	Recurrence noted in February, 1909, by patient February 1909 Examination recurrence at new external ring Advised to wear truss March 1911 Examination ring admits finger tip, but hernia is kept back by truss "It has not been down for 3 years, therefore clinically is perfect"
22032 ♂, 22 C	Feb 28 1908 Ether Conjoined tendon well developed Slight split in fascia of external oblique Sac ligated with heavy silk Cord not transplanted Cremaster sutured under internal oblique Healing per primam	July, 1918 Letter from patient "Hernia comes down when I work hard" Statement by physician, "Place of operation seems to be swollen size of pigeon's egg and when patient coughs there is a slight protrusion on operated side"
25705 ♂, 21 Misc	April 5, 1910 Gas Condition of structures not described A mass of extraperitoneal fat which lay inside the cremaster interfering with closure excised Cord not transplanted Fine silk used in closure except at lowermost angle, where a heavy suture was used Healing per primam	Patient says he first noted a recurrence in about 7 months July, 1918 Letter from patient, "Recurrence took place November, 1910" Physician's statement, "The rupture is in a little better condition now than before operation Operation seemed a success for several months when the hernia became troublesome again"
26370 ♂, 37 Misc.	Aug 8, 1910 Ether Double hernia Conjoined tendons good on both sides Left side high ligation of sac with heavy silk cord not transplanted, cremaster drawn under internal oblique Right side no sac prehernial weakness, cord not transplanted, similar closure Healing per primam on both sides	Recurrence on left in about 1 year and on right in 2 years July, 1918 Examination, small direct recurrence on left femoral hernia on right and small rent in aponeurosis through which a little fat protrudes Findings confirmed at operation March 30 1920 Two recurrences
27600 ♂, 36 J	April 19, 1911 Ether Condition of conjoined tendon not described Neck of sac transixed and ligated high Cord not transplanted Cremaster drawn under internal oblique Healing per primam	July, 1918 Letter from patient, "For the past 4 years I have a partial descent" Subsequent letters unanswered.
28848 ♂ 21 I	Dec 15, 1911 Ether Conjoined tendon good External pillars flabby fairly well defined also internal pillars Sac twisted and transixed Cord not transplanted Cremaster drawn under internal oblique Healing per primam	Recurrence in 4 years Oct 9, 1915, second operation, "D" Recurrence found midway between pubes and internal ring No evidence of rupture along cord Cord transplanted No subsequent report

* ♂ represents male

TABLE 17—RECURRENTS OF INDIRECT HERNIA—CONTINUED

Surg No Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
30247 ♂, 47 H	July 18, 1912 Ether Internal oblique and cremaster poorly developed Conjoined tendon not described Sac ligated high and transfixed Cord not transplanted Cremaster drawn under internal oblique. Healing per primam Postoperative broncho pneumonia	July 1918 Report from physician "Almost ever since operation left side has been weak A knuckle of intestine seems to bulge into the left internal ring and almost into scrotum"
30273 ♂ 31 H	July 20 1912 Gas and ether Condition of structures not described except that internal oblique was rather far separated from Poupart's and there was a rather large opening at posterior thin spot Cord not transplanted Closure—cremaster drawn under internal oblique Healing per primam	July, 1918 Letter from patient, "Recurrence in about 1 year Wearing truss" No report from physician
30374 ♂ 32 M	Aug 8 1912. Ether Conjoined tendon obliterated All structures weak High ligation of sac Veins excised Cord not transplanted Cremaster drawn under internal oblique Two small suture abscesses Wound drained 10 months	Recurrence in about 1 month after leaving hospital Aug 9 1917 second operation "O" Layers of aponeurosis of external oblique had been overlapped and these were retracted backward Recurrence found in outer angle of wound Cord not transplanted Cremaster very thin but it was used under internal oblique. July 1918 Report from physician "Cured"
30456 ♂, 57 M	Aug 26, 1912 Ether Conjoined tendon poor Very little cremaster and much fat present, patient weighing 201 pounds No sac found Cord not transplanted Hernia was of sliding variety therefore closure difficult It was impossible to get a good apposition of structures without some fat between Cremaster drawn under internal oblique Healing per primam	Recurring in 2 months June 30 1914 second operation, "M" Recurrence found through external ring which admits five fingers Sac protruded through separated cremaster muscle Veins excised Layer of fascia lata used over external oblique Silk used through out Long and difficult operation Castration advised, patient refused No subsequent report
32488 ♂ 47 D	June 5 1918 Ether Conjoined tendon not described Sac closed by transfixion Cord not transplanted Cremaster which was exceptionally strong aided considerably in closure Healing per primam	July, 1918 Letter from patient, "Slight rupture on right side though it does not descend into scrotum" No report from physician
32746 ♂ 70 M	Aug 26, 1918 Gas and ether Conjoined tendon good Hernia as large as two fists Sac densely adherent as patient had worn truss for years Sac ligated by transfixion and a running mattress suture followed by ligation en masse Cord not transplanted Cremaster drawn under internal oblique Healing per primam	Recurrence noticed in 7 months March 31, 1914 second operation "J" Recurrence found at inner angle along cord Cord not transplanted Conjoined tendon very good indeed and it seemed that in the previous operation this structure had not been properly included in the sutures Hydrocele found March 22 1916 Castration July, 1918 Examination no recurrence Perfect result
35500 ♂ 67 M	Oct 14 1914 Ether Conjoined tendon not described Sac ligated with silk from inside followed by multiple transfixion and ligature en masse Cord not transplanted Cremaster drawn under internal oblique Healing per primam	Nov 22, 1915 patient was operated on again at Church Home by Dr Bloodgood Recurrence was found anterior to the cord "Marked fibrosis of muscles No signs of infection"
41358 ♂, 80 O	Dec. 7, 1916 Ether Conjoined tendon not described Thick walled adherent sac. Neck twisted, transfixed Cord not transplanted Cremaster drawn under internal oblique Healing per primam	July 1918 Letter from patient "Recurrence on left side in April 1918 size of walnut" (position of recurrence not mentioned)

* ♂ represents male.

TABLE 18—RECURRENCES OF DIRECT HERNIA

Surg No, Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
8511 ♂, 50 B	Jan 12, 1899 Cocain Conjoined ten don firm Internal oblique divided and transplanted Closure of neck of sac difficult and accomplished "roughly" Cord transplanted Healing per primam	Recurrence, patient states, a few months after operation Jan 12, 1904 Examination recurrence at upper and lower angle of wound On account of patient's age, operation not advised
9144 ♂, 39 L	July 11, 1899 Ether Conjoined ten don obliterated Great deal of fat and fascia in wound Cord not transplanted Rectus withdrawn from sheath and transplanted Difficult closure Ether badly taken Healing per primam	Recurrence in 6 years May 11, 1905, second operation, "F" Recurrence found below lowermost edge of transplanted rectus muscle Internal oblique and conjoined tendon weak Cord not transplanted No subsequent report
10944 ♂, 35 L	Oct 10, 1900 Ether Conjoined ten don not wide Veins excised Vasc not transplanted Healing per primam	Recurrence in 13 years Oct 9, 1913, second operation, "J" Recurrence found at lower end of wound Structures fairly good Large rent in lower end of wound which ran directly into peritoneal cavity Cord transplanted Rectus not used No subsequent report
21471 ♂, 37 G	Oct 25 1907 Ether Conjoined ten don weak Cord not transplanted Suture included sheath of rectus, which was not transplanted, however Healing per primam	Recurrence in 2½ years March, 1911 Examination recurrence at lowest extremity of incision on left side, direct hernia on right No subsequent report
21711 ♂, 32 G	Dec. 20 1907 Ether Conjoined ten don fairly well developed Pillars ring poorly developed Edge rectus firm Cord not transplanted Cremaster sutured between internal oblique and Poupart's Healing per primam	Recurrence in 1 year Jan 15, 1909, second operation, "G" Recurrence found at lower angle of wound Conjoined tendon weak On account of obliterated scar tissue accurate anatomic sutures scarcely possible No subsequent report
22301 ♂, 50 K	May 16 1908 Ether Conjoined ten don good, aponeurosis external oblique weak Sac ligated high Cord not transplanted Cremaster sutured to internal oblique Healing per primam	Recurrence in 2 years March 25, 1911, second operation, "N" Recurrence found at inner angle under conjoined tendon Neck of sac transplanted High ligation No subsequent report
24935 ♂, 64 O	Nov 8, 1909 Cocain Condition of structures not described Patient extremely fat Cord not transplanted Operation as at present cremaster drawn under internal oblique Infection in middle of incision	Recurrence in 6 months June, 1910 Examination sac bulges through ring Sinus at about middle of incision Probed—no ligature found July, 1918. Examination large recurrence Is wearing truss
26018 ♂, 22 O	May 30, 1910 Ether Condition of structures not described Sac extremely adherent to bladder High closure impossible owing to proximity of bladder Cord not transplanted Closure—using cremaster under internal oblique Healing per primam	July 1910 Examination patient complains of swelling just below external ring "This swelling is evidently composed of fat and difficult to reduce Whether it is a recurrence, or fat which is adherent to the bladder and was impossible to dissect at operation, it is difficult to say" January, 1919 Letter, "I am wearing truss and plan to have another operation done"
27037 ♂, 21 O	Dec 17, 1910 Ether Conjoined ten don obliterated Cremaster well developed Remaining muscles weak Cord not transplanted Closure with transplantation of rectus flap from sheath of rectus in lower portion and cremaster under internal oblique High closure Healing per primam	Recurrence 3 months after operation Dec 18, 1912, second operation, "M" Recurrence at site of former operation Sheath of rectus again used Veins excised Good closure

* ♂ represents male.

TABLE 18—RECURRENCES OF DIRECT HERNIA—CONTINUED

Surg No, Sex,* Age, Operator	Details of Operation	Evidence of Recurrence
27777 ♂ 20 N	May 10, 1911 Gas and ether Conjoined tendon firm Cremaster not well developed Dissection of sac difficult owing to fat in the wall Separation between muscle and Poupart's ligament seemed unusually wide Cord not transplanted Cremaster drawn under internal oblique Wound became infected opened irrigated and packed	Recurrence shortly after operation July, 1918 Examination hernia has recurred on right side
28526 ♂ 48 Misc	Oct 9, 1911 Gas and ether Condition of structures not described Veins excised Vas transplanted Conjoined tendon edge of internal oblique and transversalis sutured to shelving margin of Poupart's Cut gut and silk for closure Healing per primam	July, 1918 Letter from patient "By fall was again ruptured" Two subsequent letters unanswered
31688 ♂, 48 J	March 13, 1913 Ether Conjoined tendon rather weak Right direct and indirect sacs Indirect sac empty Direct sac encased in layers of fat Stump retracted under internal oblique Cord not transplanted Cremaster very much thinned out, not used in closure Firm closure obtained Healing per primam	July, 1918 Letter from patient who is a physician "Slight recurrence" No conclusive evidence of recurrence is submitted Subsequent letters unanswered
33082 ♂, 52 J	Oct 25, 1913 Ether - All structures weak Conjoined tendon obliterated Sac bulges and there is a tendency to formation of indirect sac also Cord transplanted Sheath of rectus so weak that it was not used in the repair Later, however, it was successfully used to cure the recurrence Border of internal oblique sutured to Poupart's ligament with remnant of conjoined tendon Healing per primam	Recurrence in 7 months Oct 11, 1916 second operation, "D" Recurrence found directly through abdominal wall Flap of rectus sheath used to reinforce tissues in region where previous recurrence had taken place Lengthy operation on account of dense fibrous tissues July, 1918 Report from physician, "Strong scar"
33324 ♂, 53 J	Nov 25, 1913 Ether Direct and indirect sacs on right side Condition of structures not described except that cremaster was fairly well developed Cord not transplanted Cremaster drawn under internal oblique On discharge very slight bulging at upper end of scar	July 1918 Examination small recurrence on right side
35509 ♂ 52 M	Oct 17, 1914 Ether Structures for repair extremely weak especially conjoined tendon Cord transplanted Bassini closure Healing per primam	Recurrence 3 years after operation July 1918 Examination recurrence on right side
36842 ♂ 38 D	April 25 1915 Ether Structures quite weak particularly internal oblique. Practically no conjoined tendon Cord transplanted Cremaster drawn under internal oblique Healing per primam	Recurrence in about 2 years July, 1918 Letter from patient's physician "Recurrence is about 2½ inches above external inguinal canal There is very little trouble caused by it"
39728 ♂ 46 D	May 6 1916 Ether All structures exceedingly weak No special note as to treatment of cord Closure, cremaster drawn under internal oblique Reinforcement with fascia transplant—from right thigh Healing per primam	October, 1916 Examination by 'D' Recurrence at external ring" Subsequent letter unanswered

* ♂ represents male

ARCHIVES OF SURGERY

rectus muscle in functioning would tend to draw back into its normal position

Excision of the veins of the cord undoubtedly lessens the likelihood of recurrence, but it is followed by hydrocele in almost 20 per cent of the cases, when this procedure has been omitted, hydrocele developed in less than four per hundred. Splitting of the cord with transplantation of the veins was performed in forty-seven cases and in eight recurrences (17 per cent). It is interesting to note that in six of these eight cases, the recurrence was found at the site of transplanted veins.

The use of local anesthesia slightly increases the rate of recurrence but does not seem definitely to have affected the healing of the wound.

The liability to recurrence after operation for strangulated hernia where drainage is not used and with healing by first intention is, as might be expected, not greater than in the ordinary type of hernia.

Infection of the wound greatly increases the liability to recurrence. The percentage of recurrence in the direct hernias is 18.08, and in indirect, 5.63.

The mortality, deducting the cases of strangulated hernia, is a little less than half of 1 per cent.

The lines which this study should follow were indicated by Dr. Bloodgood's exhaustive analysis of the facts concerned in the operative treatment of hernia on which failure and success seemed to depend on the relative values of new methods such as the excision of the veins, the splitting of the cord and transplantation of the veins, the transplantation of the rectus muscle and of the sheath of this muscle were more or less definitely appraised. Dr. Bloodgood announced the discovery that hydrocele was likely to follow excision of the veins and told of the conditions under which swelling and atrophy of the testicle might be expected. Thus were emphasized the particulars to be observed by the recorders in their descriptions of the operations for the cure of hernia, and hence it is that there is usually found noted in the histories the details without which an investigation of this kind would be futile. It is unfortunate that this remarkably fruitful monograph by Dr. Bloodgood is not more widely known.

The percentage of recurrence in the cases, traced from time to time through many years and now systematically reviewed, is so high that the purpose in publishing the results is not likely to be misinterpreted. Failures are emphasized in the effort to determine and correct the causes.

Undoubtedly one of the most essential features of the operation is the high ligation of the sac. This fact has been well brought to the attention of the profession by the fairly good results obtained by the

simple operation of Kocher and by the suggestive papers of Laméris,¹³ who by his experiments on the human subject seemed to have convinced himself that suture of any of the tissues between the peritoneum and skin was superfluous

Thus there may remain, as Dr Halsted believes, little of the original operations of Bassini and himself that is essential except the free and clear exposure of the entire canal which makes possible the high ligation of the sac. The transplantation of the cord and the attempt (quite futile) to reestablish the obliquity of the canal may be omitted, even the suture of the internal oblique muscle to Poupart's ligament may prove to be an unnecessary detail provided the cremaster muscle is well developed and properly utilized

It is impossible to arrive at a definite conclusion as to the value of transplantation of the cord in preventing a recurrence from the material secured by this study. From the figures below it seems that the percentage of recurrence is very much higher in those cases in which the cord is transplanted but this may be explained by the fact that transplantation of the cord has not been used in recent years save in those cases with exceedingly poor structures. It is by no means a settled procedure, however, to transplant the cord even in such cases and several of the surgeons operating here at present believe that transplantation of the cord increases the likelihood of recurrence in all cases. The influence of the cord is strikingly illustrated by the fact that there is no record of a single recurrence after excision of the cord

Dr Halsted believes that a long series of operations performed by one man will be necessary to determine the influence of transplantation of the cord on recurrence and he suggests that it would be wise for transplantation to be performed in alternate cases throughout the series regardless of the condition of the structures. Careful following up of the cases will be necessary throughout a long series of years

The cremaster muscle has rarely been mentioned by writers on the subject of the cure of hernia. If it is advantageous to suture the free edges of the internal oblique and transversalis muscles to Poupart's ligament, may it not be still more so to make use of a muscle morphologically a part of the internal oblique which normally has a broad attachment to the under surface of the aponeurosis of the external oblique, in other words, to this ligament? The upper bundles of the cremaster may be hardly distinguishable from those of the

13 Laméris, H. J. Zur Behandlung der indirekten Leistenhernia, *Deutsch Ztschr f Chir* **119** 569, 1912, Ueber die Operation des Leistenbruches, *Zentrabl f Chir* **45** 764, 1918

internal oblique, their attachments to Poupart's ligament being almost in line with those of the latter muscle. The free edge of the internal oblique, particularly in its lower part, may not infrequently be approximated to Poupart's ligament only with difficulty and under tension, and the surgeon may have to content himself with suturing it to the fibers of the aponeurosis of the external oblique, which take no part in the formation of Poupart's ligament. Why should we cut away a muscle which so naturally falls into the place where it can serve such a good purpose? When a well developed cremaster muscle, spread out, is mattress-sutured without the slightest tension to the under surface of the internal oblique, it glides into and fills the hollow just vacated by the hernial sac and its contents and may well give the surgeon cause for speculation as to what more is to be gained by suturing the free edge of the internal oblique to Poupart's ligament. Probably something is, however, to be said in favor of this maneuver which is essentially an overlapping of the bundles of one part by another part of the same muscle.

Briefly then, we have in the cremaster a muscle already firmly attached to Poupart's ligament slightly internal to the very line to which we hope to make, with the aid of sutures, the free border of the internal oblique adhere. We must bear in mind the possibility that this border, normally free, may disengage itself when the muscle sutured, perhaps under tension, comes into play. The cremaster muscle, on the other hand, might be expected to remain in the position so naturally assumed. Not infrequently the cremaster is quite as well developed as it was in the case from which the artist, Max Brödel, made the admirable drawing, here reproduced, from Dr Halsted's paper.⁹

A study of the operative notes of all cases of recurrent hernia shows definitely that the overlapping of the aponeurosis of the external oblique is permanent. The rectus muscle when sutured to Poupart's ligament pulls away from its new attachment, leaving a few scattered bands bound up in masses of scar tissue. The free edge of the internal oblique does not always remain permanently attached to Poupart's ligament, it may undergo fibrous change and in several instances it has been difficult to find the edge of the muscle in the mass of fibrous tissue.

The overlapping of the aponeurosis of the external oblique helps to draw the free edge of the internal oblique to Poupart's ligament and hence to lessen the tension on the sutures placed to hold these two structures in contact. I have demonstrated this recently on the cadaver, and as the overlapping has been found to be permanent it would seem to be a step in the operation that should not be omitted.

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REPORT ON TETANUS*

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PHILADELPHIA

I PATHOGENESIS OF TETANUS

The following propositions may be accepted as proved¹

A *The Nature of the Disease*—The disease is a pure toxemia, the bacilli or their spores may exist indefinitely in the tissues, and no symptoms will be produced unless toxins are formed

It is important to realize, as pointed out by Tulloch,² that at least three different strains of toxic *B tetani* are recognized, and more than one nontoxic strain. And one must not forget the necessity for symbiosis of the spores of tetanus bacilli (and even of the bacilli themselves) with certain other organisms before a toxin can be produced. Tulloch³ found *B welchii* and *Vibrio septique* very valuable in experimental work, while the simultaneous presence in the wound of the pyogenic organisms has long been appreciated as a predisposing factor of the greatest importance

B *Tetanus Ascendens*—In experimental tetanus, when small animals are used, the form known as tetanus ascendens occurs. Here the symptoms of the disease begin in the inoculated extremity and, though other neighboring parts may become affected subsequently, yet death or recovery usually occurs before trismus and retraction of the head develop. In the larger animals and in man, however, the symptoms usually begin first in the muscles of the neck and jaws, no matter where the point of inoculation, subsequently the muscles of the back and trunk are affected, and finally the extremities. This form of the disease is known as tetanus descendens

*Presented before the Societe Internationale de Chirurgie, Paris, July 1920

1 The evidence on which they are based is detailed at length in a monograph by Ashhurst and John (The Rational Treatment of Tetanus, Am J M Sc **145** 806, 1913, *ibid* **146** 77, 1913). All references prior to that date may be found there

2 Tulloch, W J Proc Roy Soc, London **40** 529 (Series B) 1917-1919

3 Tulloch, W J Brit. M J **1** 164 (June) 1918

The explanation of this difference resides in the different methods of inoculation. In experimental animals, the toxin is usually injected into muscle, comes into immediate relation with the motor nerves, is absorbed rapidly by them, and the part of the spinal cord first to be affected is that in anatomic relation with the wounded limb. In man, however, the usual point of inoculation (in civil life, at least) is the hand or foot, and much of the toxin enters the general circulation and is carried to the end-plates of all nerves throughout the body, and the toxin which is thus carried to such short nerves as those of the facial, cervical, and spinal muscles will reach the spinal cord through these short nerves, and will begin to produce tetanic spasm in the parts supplied by these short nerves, even before the toxin in the wounded extremity has had time to ascend the nerves of that extremity as far as the anatomically related region of the spinal cord. Tetanus following wounds of muscular parts in man is not infrequently inaugurated by symptoms of local tetanus.

C Course of the Toxin—It is a fact that the toxin ascends the peripheral nerves to the spinal cord.

The peripheral nerves have little power of neutralizing the toxin—no more power than has the liver, for instance. After death, toxin may be recovered from the nerves as readily as from the internal organs. The peripheral portions of the nerves are found to give up more toxin than those portions nearer the spinal cord. In other words, the nearer the toxin gets to the spinal cord, the more impregnably entrenched does it become in the nerve tissue, and the readier the access of the toxin to the central nervous system, the less is the amount required to kill.

The toxin ascends the nerves (1) by way of the axis cylinders (perhaps by means of a centripetal protoplasmic current), and (2) by way of the lymphatic channels of the epineurium and perineurium.

What proportion of toxin ascends by each of these channels does not appear to have been determined. The researches of Robertson⁴ and of Teale and Embleton,⁵ however, indicate that the lymph channels are of more importance than they were formerly thought to be. Robertson's experiments further indicate that the toxin gains access to the cord through the motor roots.

When the toxin has reached the spinal cord it spreads to neighboring parts of the cord, both to the sensory side and to the neighboring motor regions.

Tetanus dolorosus may be produced experimentally by injecting toxin into the sensory nerve roots, and the animals will die of exhaustion before motor phenomena develop.

D Production of Tetanic Symptoms—The toxin also enters the general circulation, but only when this toxin reaches the spinal cord does it produce characteristic tetanic symptoms.

In animals, rapid emaciation sometimes follows the administration of tetanus toxin, when no tetanic symptoms are produced, probably these cases, described as *tetanus sine tetano*, are due to the action of the toxin on structures other than the nervous system.

⁴ Robertson, H. E. *Am. J. M. Sc.* **152** 31 (July) 1916.

⁵ Teale, F. H., and Embleton, D. *J. Path. & Bacteriol.* **23** 50 (Oct.) 1919.

It is probable that most of the toxin which reaches the central nervous system from the general circulation does so only indirectly through absorption by peripheral nerves. Albert⁶ contends that most of it is carried directly to the central nervous system by the blood, but he presents no evidence to disprove the former theory, which has recently been confirmed by the researches of Teale and Embleton⁵

E *Cause of the Symptoms of Tetanus*—The toxin stimulates the motor cells of the spinal cord, with the result that the muscles controlled by these cells are thrown into tonic spasm, the toxin also renders the sensory side of the cord extremely susceptible to external stimulus, so that very insignificant stimuli, such as the slamming of a door, jarring the patient's bed, a sudden draught of air, etc., will bring on a clonic convulsion, or at least will greatly intensify, for the moment, the tonic spasms

II PROPHYLAXIS OF TETANUS

A Certain classes of wounds, received in certain surroundings, are more often followed by the development of tetanus than are ordinary wounds. *B. tetani* normally infests the intestinal tract of horses and cattle and is deposited with their dung, it is found in the intestinal tract of perhaps 5 per cent of mankind. Therefore wounds contaminated with barnyard or highly cultivated garden soil, those produced by dragging in street dust, etc., are especially liable to be infected with tetanus bacilli. Gunshot wounds are liable to contamination not *per se*, but only as these conditions, and others presently to be mentioned, obtain

Growth of the organisms is favored by anaerobic conditions of the wound. These are present in any wound in which there is tissue destruction, which implies cessation of circulation in the devitalized tissues, the best culture medium for tetanus bacilli is that which contains some dead organic tissue. Contused, lacerated and gunshot wounds offer ideal conditions for the development of any bacilli present, and as the bacilli are carried into the wound only by a missile (shell fragment, fragment of clothing, splinter of wood, rock, etc.) and usually remain attached to this missile, it follows that wounds with retained missiles offer the most favorable conditions possible for the development of tetanus. Punctured wounds are to be dreaded not because the vulnerating instrument is retained, which it seldom is, but (1) because it was contaminated either even before it pierced the skin, or (2) because it carried infection from the skin or clothing deeper into the tissues. Even a superficial brush-burn may give rise to tetanus (as in a case in my own experience) provided the skin or the vulnerating surface carries tetanus bacilli

6 Albert Compt rend Soc de biol 81 1127, 1918

B Care of the wound is the first step in the prophylaxis of tetanus. It is my own firm belief that efficient care of the wound as soon as possible after its receipt is by all means the most important feature in prophylaxis.⁷

This includes (1) mechanical cleansing (*débridement*, extraction of foreign substances, excision of devitalized tissue), and (2) chemical disinfection (3 per cent alcoholic solution of iodine remains, in my own opinion, the best agent for this purpose, certainly no cauterizing agent should be used, as this will produce more dead tissue).

C Prophylactic use of antitoxin holds second place, but second only to care of the wound.

The fact that antitoxin is of use as a prophylactic injection scarcely needs discussion. Accumulated experience during the recent war merely served to emphasize its value as already ascertained in civil life. In the War of the Rebellion there occurred, according to Sanford,⁸ 505 cases of tetanus among 246,172 wounded, or a little over two per thousand. In the American Expeditionary Forces, during the recent war, according to figures furnished to me by the Office of the Surgeon-General, U S Army, there developed thirty-six cases of tetanus among 223,067 wounded, or less than two per 10,000. Even allowing for the vast improvement in the mechanical and chemical disinfection of the wounds, such a remarkable diminution in the incidence of tetanus could never have been secured without antitoxin, especially in view of the highly contaminated nature of the soil in which much of the fighting was done.

Reference may further be made to the communications of Bazy⁹ who observed 200 wounded from the same sector, of whom 100 received serum when wounded and only one developed tetanus (the day after the injection), while the remaining 100 received no serum, with the occurrence of eighteen cases of tetanus, of Columbino¹⁰ who narrates that among 200 wounded received in his service, all but two had received a prophylactic injection of serum, and only these two developed tetanus, of Walther¹¹ whose service received 270 wounded German prisoners, to as many of whom as possible antitoxin was given, with the result that of the whole number nineteen developed tetanus, only one of these cases being in a patient who had received the serum (and in his case the disease appeared the day after the injection), of Fredet¹² who observed twelve wounded German prisoners (to whom the German surgeon left in charge refused to administer proffered French antitoxin, because he believed it to be of no value) six of whom developed tetanus, while among a larger number of serum-treated French (wounded in the same battle, and in

7 The report by Clark (Boston M & S J **176** 541, 1917) of 100 consecutive cases of punctured wounds of the foot, produced by nails, without a single bad result, and the fact that no tetanus antitoxin was employed, indicates the efficiency of prompt and proper care of the wound.

8 Sanford Internat A M Museums Bull, 1918, No 7, p 365

9 Bazy Bull Soc chir, Paris **42** 2919, 1916

10 Columbino Bull Soc chir, Paris **42** 2913, 1916

11 Walther Bull Soc chir, Paris **43** 71, 1917

12 Fredet Bull Soc chir, Paris **43** 1338, 1917

an adjoining ward) not one developed tetanus. And especially would I call attention to that graphic representation¹³ of the prophylactic value of antitoxin which gives a curve constructed from Sir David Bruce's reports¹⁴ of the incidence of tetanus in the British army, indicating an incidence of from fifteen to thirty-two cases of tetanus per thousand wounded until tetanus antitoxin was administered as a matter of routine to all the wounded, whereupon the incidence fell to two or three per thousand and never subsequently exceeded these figures. Nor against these facts can it be argued that tetanus was prevalent only at the first Battle of the Marne, for as Leriche¹⁵ points out, it was prevalent also in other sectors wherever serum was not available for prophylaxis, and it complicated even clean perforating bullet wounds which neither then nor at any other period of the war were treated by operative disinfection, yet in these wounds as well as in wounds which received operative treatment the incidence of tetanus became negligible whenever serum was available. The fact that the wounded of the British army when cut off in Kut-el-Amara began to develop tetanus, but that the incidence fell at once to its previous low figure when an aviator arrived with a supply of antitoxin, and its prophylactic use was resumed¹⁵—this, I say, is but another proof of the prophylactic value of antitoxin.

There are three factors to be considered in connection with the prophylactic use of the antitoxin: (1) the quantity to be administered, (2) the site of the injection, and (3) the frequency with which it should be administered.

1 *The Quantity of the Injection*—The usual prophylactic dose is 1,500 units, U S A.

The United States Government's standard method for testing the strength of tetanus antitoxin is: "The immunity unit for measuring the strength of tetanus antitoxin shall be ten times the least quantity of antitetanic serum necessary to save the life of a 350-gram guinea-pig for ninety-six hours against the official test dose of the standard toxin furnished by the Hygienic Laboratory of the Public Health Service." The official test dose of toxin is one hundred times the smallest quantity of toxin which will kill a guinea-pig within ninety-six hours.

Taking the average weight of persons injected as 150 pounds (70 kilograms), and calculating the potency of the antitoxin from the known value of a unit (U S A), it is evident that 1,500 units is a little more than 2,000 times the minimal lethal dose of toxin in such an individual. Such an amount is by no means excessive, in view of the fact that the amount of antitoxin required to prevent death increases in geometric progression with the lapse of time. After the lapse of one hour, twenty-four times as much antitoxin is required as when antitoxin and toxin are injected simultaneously (Remertz, 1911).

13 Editorial, Arch med Belges 70 834 (Sept) 1917

14 Bruce, David Brit. M J 1 118 (June 27) 1917

15 Leriche Bull Soc chir, Paris 43 76, 1917

2 *The Site of the Injection*—Usually it is administered subcutaneously. It is better, however, to administer it intramuscularly, in the immediate vicinity of the wound, in order to flood these tissues with antitoxin even before the absorption of toxin has begun. The antitoxin so injected finds readier access, it is believed, to the nerves of the wounded part, and is admitted to the circulation no less rapidly than when administered by the subcutaneous route.

3 *The Frequency of the Injection*—The first injection should be given as soon as possible after the receipt of the wound. In military surgery, the first injection almost always can be given some hours before proper care of the wound can be instituted. This fact is fortunate for the wounded man because of the frequency with which operation must be delayed, but in neither military nor civil life does this in any way impair the doctrine that proper care of the wound is the more important of the two factors in the prevention of tetanus.

It is a well demonstrated fact that the antitoxin is all eliminated from the system in about eight or ten days after the injection. Its quantity remains practically undiminished for a week and then rapidly diminishes to nothing in the course of two days. As the tetanus bacilli, if any are lodged in the wound, may not begin to produce any toxin until at least as long a time as this has elapsed, it is manifestly important that some antitoxin should be present in the system as long as the probability of the presence of toxin persists. In many cases in civil life (vaccination wounds, for instance) tetanus bacilli do not enter the wound at the time of its receipt, but are introduced secondarily by the carelessness of the patient in neglecting to return for dressings and in attempting to care for the wound in septic surroundings at home. But even if present in the wound from the first, the bacilli may lie dormant for weeks in the form of spores, before development occurs with the production of toxin.

The necessity for a second injection of antitoxin about the eighth or tenth day is thus very evident, and I have come to agree with Solieri (1910) who insisted that this injection must be renewed every eight or ten days thereafter until all necrotic tissues are removed and there is a clean granulating surface. The dose should be the same in the later injections as in the first.¹⁶

16 Vallee and Bazy (Compt rend Acad d sc 164 1019, 1917) have pointed out that the organism utilizes subsequent doses less and less, the greater the time that has elapsed since the first dose, perhaps because it in time develops an anti-antitoxin. So that even if the supply of toxin gradually becomes less as the time elapsed since injury increases, the dose of antitoxin must be maintained at the original amount, or even be increased. The researches of these writers indicate that it may become possible to produce active immunity against tetanus by vaccination with iodized toxin, and that this active immunity may be of more value in cases of late or chronic tetanus than the progressively diminishing strength of passive immunity which is conferred by the serum.

That tetanus may develop after the prophylactic use of antitoxin cannot be denied, but such cases rarely develop very soon after the injury, and when they do appear seem to be less severe than are most cases in which no serum has been administered

Speed,¹⁷ working in a British base hospital, observed six cases among 12,000 wounded, three of the patients recovered

Mathieu¹⁸ noted that tetanus which developed after the prophylactic use of serum gave a mortality of 26.6 per cent, while the mortality was 58.1 per cent among those who had not received antitoxin, while Gessner and Adiger¹⁹ report that among eleven patients who developed tetanus in spite of the prophylactic use of antitoxin (only one injection having been given in each case), there were only four deaths, a mortality of 36.3 per cent, which is to be compared with the general mortality in the same hospital, which has varied from 64 to 78 per cent since the introduction of serum treatment. These figures indicate that even a single prophylactic injection tends to reduce the mortality

These early postserum cases, a class which our French colleagues have happily named "tetanos post-serique precoce," are certainly rarer than the late postserum cases ("tetanos post-serique tardif"), and it is undoubtedly due to the nearly universal employment of serum prophylactically that we must attribute the relative frequency during the recent war, of forms of tetanus rarely encountered in civil life. I mean the late, the local, the recurrent and the chronic forms of the disease

A distinction should be made between late tetanus (that in which no primary attack occurs under four weeks after injury), local tetanus (which corresponds to the experimental form known as tetanus ascendens, except that it never becomes general), chronic tetanus (that which is of long duration, irrespective of other factors, which usually is relatively mild, and which sometimes leaves contractures as a legacy), and recurrent tetanus (in which a primary attack is followed by others). The incubation period scarcely ever exceeds four weeks, and in late or recurrent cases it should be dated from the arousing injury or operation, not from the original wound.²⁰ Speed²¹ has recorded a remarkable instance of recurrent tetanus. A soldier wounded in August, 1916, whose wound healed without operation, received three doses of antitoxin in the first ten days after injury. Chronic tetanus developed in October, 1916, recovery was complete by February, 1917. Recurrence was noted in January, 1918, there having been no new wound and no operation since the original injury. A roentgenogram at this time showed a retained foreign body

17 Speed Med & Surg, St Louis **1** 14, 1917

18 Mathieu Arch de med et pharm navales **106** 467, 1918

19 Gessner, H. B., and Adiger, D. New Orleans M & S J **69** 91 (Aug) 1916

20 Hesse Deutsch Arch f klin Med **24** 284, 1917

21 Speed Med & Surg, St Louis **2** 499 1918

This leads to a discussion of the prophylactic use of serum before late operations on parts which have been wounded in war or in other circumstances in which contamination with tetanus bacilli is feared. This subject was very fully discussed in 1917 by the Society of Surgery of Paris. As Fredet²² points out, it involves answers to three questions:

(a) What is the frequency and gravity of cases of tetanus occurring late, in spite of early prophylactic use of serum at the time of injury?

(b) What is the frequency, nature and gravity of accidents due to reinjections?

(c) What is the efficacy of reinjections in preventing late tetanus?

(a) To the first of these questions, surgeons have replied by submitting long lists of operations on such wounds with no, or at most with very few, occurrences of tetanus, and the cases that have occurred usually were mild. Fredet himself had only one patient develop tetanus (a mild case with recovery) among about 1,000 who underwent late operation, none of these patients having received a reinjection at the time of operation. But we cannot ignore the significance of certain facts to the contrary, which will be cited subsequently in the discussion of Fredet's third question.

(b) It is an accepted fact that accidents ("serum sickness," anaphylaxis) due to reinjections are neither frequent nor serious. Cases of death from anaphylaxis are almost, if not quite, unknown. The fatal case related by Salvatore²³ as one due to anaphylaxis may as readily be attributed to sepsis (local tetanus in case of undrained wound of the elbow joint with retained missile). Accidents such as erythema, urticaria, and even articular effusions undoubtedly are regrettable, and are an annoyance to the patient, but they just as certainly are less annoying than would be the outbreak of tetanus. Moreover, according to certain observations, it is probable that the antitoxin, if administered at the time of operation while the patient is under a general anesthetic, will produce no anaphylactic shock. Acting on the suggestion of Major James F. Corbett, M. C., U. S. Army (who had found it impossible to produce anaphylaxis in experimental animals which under other circumstances were very susceptible to repeated doses of antitoxin), I inaugurated this practice while chief of the surgical service at the Walter Reed General Hospital, Washington, D. C., and a prophylactic injection of antitoxin was administered subcutaneously to each patient while he was under the influence of

²² Fredet. *Bull. Soc. chir., Paris* **43** 1108, 1917.

²³ Salvatore. *Gazz. d. osp.* **38** 5 (Jan. 4) 1917.

the general anesthetic at the time of any operation on parts which had been wounded in a manner to suggest the possibility of their contamination with tetanus bacilli. No anaphylactic shock was observed in any case. I learned later that precisely the same conclusion as was reached by Major Corbett had been previously reported by Dean,²⁴ who even with intravenous injections administered to fourteen anesthetized patients (who had already received serum) saw no serious results—one death occurred during the operation, but there was no proof it was due to anaphylaxis, a second patient on coming out of the anesthetic had slight shock, urticaria, and edema of the eyelids, four others had urticaria, and a seventh had edema of the eyelids alone.

(c) To the question as to the efficacy of reinjections in preventing late tetanus, very significant, if not conclusive, facts may be submitted in answer. I may mention particularly the experience of Lieut-Col John F Connors, M C, U S Army, who during the war was chief of the surgical service in the Hospital Center at Savenay, France (while I was Group Consultant in Surgery). Colonel Connors writes me that among 48,000 patients who passed through this hospital center only two developed tetanus. The rule was to administer an injection of antitetanic serum to every patient who was to have an operation on parts which had been wounded. The first patient who developed tetanus had received serum at the time of injury, but six weeks later, when Dr Connors removed a large foreign body from his lung, by some oversight he did not receive another injection of antitetanic serum, he developed symptoms of tetanus within twelve hours following operation, and in spite of active treatment, death occurred in thirty-six hours. In the second case, the patient, with a compound comminuted fracture of both bones of the right forearm from a gunshot wound had likewise received antitoxin at the time of injury, but as the operation performed at the base consisted merely in manipulation of the fragments and application of a splint, no reinjection of antitetanic serum was given, twenty-four hours later symptoms of tetanus developed, but fortunately after a week of heroic treatment recovery ensued. Col James P Hutchinson, who was in command of the A R C Military Hospital No 1, at Neuilly-sur-Seine, also told me that though it was the rule to administer a reinjection to every patient at the time of a late operation on parts which had been wounded, yet it was found, in the case of two patients who developed tetanus, that this injection, by some oversight had not been given.

²⁴ Dean, H R. *Lancet* 1 673 (May 5) 1917

In this connection it is interesting to note these facts observed by Owen ²⁵ The only case of tetanus which developed among hundreds of operations for old war wounds was in the case of a soldier with nonunion of the tibia, who had had four operations for osteomyelitis, at each of which it was presumed that antitetanic serum had been given, as is the rule in the United States Army hospitals The last wound was healed by Sept 1, 1919, and an operation for nonunion (sliding bone inlay) was performed March 1, 1920 No antitetanic serum was given, tetanus developed March 7, and death occurred March 9

So that, until its uselessness is proved, I believe it is incumbent on surgeons to administer a reinjection of serum to such patients at the time of late operations on parts which have been wounded, and especially if there is a retained foreign body or a dense cicatrix rendering all the more likely the continued but latent existence of tetanus bacilli or their spores

TREATMENT OF TETANUS ²⁶

The indications are (1) to remove the source which supplies the toxin (2) to neutralize the toxin already formed, (3) to depress the functions of the spinal cord, and (4) to nurse the patient

A Removal of the Source of Supply of the Toxin—If this source is known it should be attacked directly the wound should be widely opened and mechanically cleansed of foreign bodies, sloughs, etc Then it should be treated with antiseptics, and I believe a 3 per cent alcoholic solution of iodine is the best The wound should then be filled loosely with gauze soaked in the iodine solution I believe the use of any caustic should be avoided, as it favors the growth of tetanus bacilli by the formation of sloughs If the nature of the case demands it for other reasons, amputation should be performed, then the stump should be left open and treated as the original wound Probably in many cases it will be well to follow the suggestion of Porter and Richardson to excise the related lymph nodes, particularly if they are palpably enlarged

In the case of a firmly healed wound, on the other hand, it probably will prove more detrimental to the patient to undertake any formal operation than to leave *in situ* deeply placed and apparently well encapsulated foreign bodies

²⁵ Owen Mil Surgeon 47 42, 1920

²⁶ The importance of recognizing the disease promptly can never be over-emphasized Premonitory symptoms must be recognized, and heroic treatment instituted without an hour's delay

B *Neutralization of the Toxin*—To neutralize the toxin the best remedy is antitoxin

As it may possibly still be thought by some that antitoxin is of no value in treatment, I can only recommend to these doubters to do what Delbet, himself formerly a doubter, advised, namely to study the subject. To any one with an open mind, I believe the evidence, though circumstantial and not perhaps positive, will nevertheless seem convincing. Among many other statistics, both from civil and military experience, which could be cited, these may suffice.

Mathieu²⁵ notes that 960 cases under serum treatment gave a mortality of 38.8 per cent, while forty cases not under serum treatment, gave a mortality of 80 per cent.

Dutertre²⁷ quotes Permin²⁸ who analyzed 330 cases of tetanus observed before the onset of the war. The general mortality was 62.1 per cent, among those receiving serum treatment, it was 57.7 per cent, among those receiving no serum, it was 78.9 per cent.

Other substances which are supposed to have an antitoxic effect (cholesterin, Almagia and Mendes, 1908, urea, Sewaki, 1910) have not proved themselves of value. The same may perhaps be said of phenol, according to the method of Bacelli (1893), which though employed widely and with apparent success in Italy, appears never to have given similar results in other countries. Camus (1912) showed experimentally that it had no influence on the evolution of tetanus, no matter in what amounts nor at what stage of the disease it was administered, he found that while it may possibly have some antibacterial action, it has no effect on the fixed toxin nor on the toxin in the course of fixation. Antitoxin, alone, injected simultaneously into the cerebrospinal fluid by lumbar puncture, intravenously, and subcutaneously, gave very much better results.

Exactly how the antitoxin acts on the toxin is not known. Krauss and Amiradzibi (1910), from their numerous experiments, concluded that it draws the toxin out of the cells where it is lodged, but does not itself enter into the toxin-containing cells. Recovery under the use of antitoxin they believe depends on the possibility of this diffusion, and they believe that this occurs in the human body, it being unnecessary for antitoxin to be in direct contact with toxin for it to exert its neutralizing influence on the latter.

But here, again, as in the question of its prophylactic use, we must inquire as to the quantity, the site and the frequency of the injection.

1 *Quantity of Antitoxin Injected*—No matter what the method of injection, the most important thing is to get the maximum quantity of antitoxin indicated into the patient's body as soon as possible. Delay even of a few hours may determine a fatal result, 15,000 units given within the first three hours after symptoms develop are of more value than 50,000 units given after six hours, or given in

²⁷ Dutertre. *Le tetanos et son traitement en Allemagne (1914-1915)*, Paris, 1915.

²⁸ Permin. *Mitt a d Grenzgeb d Med u Chir* 27 1, 1913.

divided doses. It should be made a rule to administer the total quantity indicated as nearly as may be all at one time, and after this overwhelming dose of antitoxin has been given, to keep the patient's system supplied with antitoxin, though in moderate amount, until his recovery seems assured. Dean²⁴ found the physiologic action of antitoxin in the blood serum could still be demonstrated as long as twenty, thirty, and even thirty-nine days after a single intravenous injection (30,000 units, U S A).

As will be pointed out later, if the antitoxin is administered subcutaneously, immense quantities are indicated. For an adult, with the usual type of case, at least 100,000 units are required in the first twenty-four hours, although a less amount may be sufficient for a child or for a comparatively mild case, one cannot be sure of the fact, and it is better to give too much than not enough. Administered intravenously, a less amount is sufficient, probably 15,000 to 25,000 units should be administered at first, and if no effect is apparent, or if the good effect wears off, a similar amount should be given after the lapse of from eighteen to twenty-four hours. If injected intraspinally, from 3,000 to 10,000 units should be given, according to the weight of the patient, this injection need not, as a rule, be repeated in less than from eighteen to twenty-four hours. Even when administered intraspinally, a certain interval must elapse before the effect of the antitoxin can be apparent. Intraneural injections, rarely used at present, should be made in as great amounts as the nerves will absorb. I have injected 1,500 units into the sciatic nerve all at one time, on several occasions, and 750 units into each of the anterior crural and obturator nerves. If the injections are slowly made, all this quantity can be introduced among the nerve fibers.

2 Site of Injection of Antitoxin—The following sites of injection deserve consideration (a) subcutaneous, (b) intraneural, (c) intravenous, and (d) intraspinal.

(a) *Subcutaneous Injections*—Thus administered, the antitoxin is absorbed by the lymphatics, transported to the veins, passes through the lungs, and finally is distributed through the arterial system to all parts of the body. Only an infinitesimal amount ultimately reaches the motor nerves through which the toxin is being carried to the spinal cord, while the greatest part is distributed to the viscera where it is of no use. This method of administration is inferior to the intravenous in the certainty and rapidity of neutralizing circulating toxin, and since overwhelming amounts are required to produce any effect it is evidently the height of extravagance so to employ it. Should it be used, at least 100,000 units, U S A, should be given.

in the first twenty-four hours I have cognizance of two cases in the Episcopal Hospital, the cost of the treatment of which may well be compared. In the first patient, antitoxin was administered subcutaneously in appropriate doses (99,000 units the first day, 65,000 units the second day, 60,000 units the third day), to a total amount of 224,000 units, and recovery followed. The cost to the Episcopal Hospital was about \$180. Shortly before this, I had under my own care a severer case of tetanus. On the first day, 3,000 units of antitoxin were administered intraspinally, on the second day, 750 units were injected into the sciatic nerve, and 750 units were injected deeply into the tissues around the wound. The patient recovered, and the total cost to the hospital for antitoxin was about \$3. The quantities of antitoxin used in each case were logically correct, but only in the second case was the mode of administration rational.

(b) *Intraneural Injections*—Since the more general adoption of intraspinal injections, the intraneural method has been less used. As it is a well ascertained fact that most, possibly all, of the toxin reaches the spinal cord only by traveling up its nerves, it is theoretically logical to inject the antitoxin into the nerves in order that, like the toxin, it may not only block the nerves against further absorption but may reach the spinal cord by the easiest road. That it will reach the cord admits of no doubt (Sawamura, 1909). Accordingly, it should be injected into the nerves at the roots of the limbs.

The conclusions reached by Teale and Embleton⁵ do not seem justified by the proof they offer. They assert that antitoxin does not reach the central nervous system by way of the axis cylinders or neural lymphatic channels any more than it does by the arteriovenous circulation. But the latter conclusions are based largely on their inability (1) to demonstrate by sensitization tests on susceptible animals the presence of horse serum in the spinal cord after it had been injected into the nerves, and (2) to demonstrate by inoculation of antitoxin into one sciatic nerve the physiologic manifestations of its presence in the lumbar cord of an animal into whose other sciatic nerve toxin had previously been injected. Now it seems not impossible that antitoxin, like toxin, may become fixed in the cord, while it may still be recoverable from the nerves.

But as it is manifestly impracticable to expose and inject antitoxin into all of the nerves throughout the body through which toxin is being absorbed, and as it is extremely probable even if not categorically proved that antitoxin when injected intraspinally acts on the toxin already in the nerve roots or spinal cord, it is nearly everywhere admitted that intraspinal are of more value than intraneural injections, especially valuable when the site of inoculation with tetanus bacilli is doubtful or unknown. The only methods we possess for

reaching all the nerves at once are (1) intravenous injections, and (2) intraspinal injections. In no case, therefore, should we depend on intraneural injections alone²⁹

(c) *Intravenous Injections*—The effects of these were studied experimentally by von Graff (1912), and subsequently by numerous other investigators. It is the surest and quickest way to neutralize the circulating toxin, and thus to prevent more of it from reaching the nerves and spinal cord, but it does not enable antitoxin to overtake and neutralize toxin already in the nerves or spinal cord, and it is the latter toxin, not the circulating toxin, which is doing the damage.

Teale and Embleton⁵ came to the conclusion as the result of their experiments that antitoxin does not pass to the central nervous system by way of the blood vessels, but that it acts simply by combining with the circulating toxin and thus prevents its reaching the central nervous system. It is true that Dean²⁴ proved that antitoxin may be found in the cerebrospinal fluid in varying, but never very large, amounts, after the intravenous administration of large amounts, but if it is of any value in the cerebrospinal fluid it certainly is more rational to insert it directly by lumbar puncture, in concentrated form, than to administer it intravenously.

(d) *Intraspinal Injections*—First used successfully in 1899 by von Leyden, who had no doubt that antitoxin was conveyed rapidly to the medullary cells after its injection into the subdural space of the lumbar cord, it is a method which is in danger of being neglected owing to modern experimental researches. But in spite of the large majority of experiments which at first sight tend to show that the intraspinal administration of antitoxin is of no therapeutic value, because it cannot be absorbed from the cerebrospinal fluid, there is sufficient clinical evidence on record to show that antitoxin can be and is absorbed into the nerve roots or cord directly from the cerebrospinal fluid. And even if this were not so, even if the *modus operandi* of antitoxin thus administered remained undetermined, that fact should in no wise hinder any rational physician from employing it by this route in the treatment of tetanus, since the clinical evidences of its value are overwhelming and irrefutable. Who does not know, except perhaps laboratory workers themselves, that the proper func-

²⁹ Pratt (New York M. J. **107** 737, 1918) adopted in one case injection (15,000 units) into the vertebral artery, one artery, he asserts, delivers blood to both sides of the body. The result is not given. He points out that the circulation from this artery goes chiefly to the medulla and cord, very little to the brain. Cocain injected into the common carotid anesthetized the head and neck without medullary involvement, so he assumes that the circulation through the circle of Willis is not free in either direction.

tion of science is to explain art, not to forbid it to employ means clinically successful because so far inexplicable by laboratory researches? The facts remain, let them speak for themselves they are both experimental and clinical, and they demonstrate beyond the shadow of a doubt that it is absolutely unjustifiable to neglect this route of administration of antitoxin in the treatment of tetanus. In addition to the now classical experimental work of Park and Nicoll³² we have the later researches by Sherrington, presented by Bruce³³ and by Andrewes,³⁴ as well as those of Golla³⁵—all of which demonstrate that if administered intraspinally antitoxin is effective. *How* it acts, may not yet be certainly known, let the laboratory workers continue their experiments until they find this out, that is their true function, but let them not dare to forbid its employment because its means of action remain unknown *ne sutor supra crepidam*. It is clinical work which here, as elsewhere in medicine, leads the way by Art, leaving the *how* and the *why* to be explained if possible by Science.

The clinical results of the intraspinal use of antitoxin are shown in Table 1

TABLE 1—RESULTS OF TREATMENT BY ANTITOXIN INTRASPINALLY

Author	Patients			Mortality, per Cent
	Number	Recovered	Died	
Luckett 1904	4	4	0	0 0
Rogers, 1905	7	4	3	43 0
Hofmann 1907	16	14	2	12 5
Perlin 1914	28	11	17	60 7
Nicoll, 1915 (collected cases)	20	16	4	20 0
Gibson 1916	4	4	0	0 0
Ashhurst, 1920	15	10*	5	33 0

* One patient died subsequently of pneumonia

It is true that in most of these patients antitoxin was given also by other routes besides the intraspinal (i e, intravenously and subcutaneously), and that other proper methods of treatment were not neglected (use of sedatives, careful nursing, etc), for tetanus is a terrible disease and must be fought with every available weapon. It must also, however, be borne in mind that the list given in Table 1 includes (at least in the case of my statistics) patients to whom antitoxin was given intraspinally so late that it is scarcely fair to

32 Park, W H, and Nicoll, M., Jr Experiments on the Curative Value of the Intraspinal Administration of Tetanus Antitoxin, J A M A 63 235 (July 18) 1914

33 Bruce, David Lancet 1 680 (May 5) 1917

34 Andrewes, F W Lancet 1 682 (May 5) 1917

35 Golla Lancet 1 686, 1917

include them in seeking to determine the value of this avenue of administration. If treatment is both efficient and early the mortality from acute tetanus probably should not exceed 20 per cent.

3 *Frequency of the Injections*—If the rule I have already enunciated be followed, namely, to administer the total quantity indicated as nearly as possible all at one time, and particularly if the intraspinal (3,000 to 15,000 units) and intravenous (20,000 to 30,000 units) methods are employed, the injections will not need to be repeated very frequently. Intraspinal injections usually are to be repeated from every twenty-four to thirty-six hours unless improvement commences, the intravenous injection need not be repeated for several days if improvement commences, but if the patient continues to get worse, and certainly if a less amount than 20,000 units has been injected at first, this amount should be repeated within from twenty-four to thirty-six hours.

4 *Technic of the Injections*—Finally, a word may be said as to the actual technic of these injections. In giving intraspinal injections for which narcosis (preferably by chloroform) usually is required, from 5 to 10 c c of spinal fluid should first be withdrawn. Then the antitoxin is slowly injected, undiluted. I have seen no harm arise from the injection of the undiluted serum, and I believe it is desirable to have it present in the cerebrospinal fluid in as concentrated form as possible. It is true that at subsequent punctures on the same patient one often finds the cerebrospinal fluid turbid or cloudy (an evidence of amicrobic meningitis), but this seems to do the patient no harm. In some cases, also, I have seen delirium follow the injection, but as the patients recovered this must be regarded as a negligible complication.

For intravenous injections it is customary to dilute the serum with saline solution up to a total quantity of 500 c c or thereabouts, and I am convinced that the injection of the undiluted serum intravenously would be injudicious because of the likelihood of producing thrombosis and perhaps embolism.

C *Depression of Function of Spinal Cord*—The third indication in the treatment of tetanus is to depress the functions of the spinal cord. This is equally important as the effort to eliminate the supply of toxin, and with those to neutralize the toxin already formed, because in almost every case there is a large amount of toxin which has become impregnably entrenched in the central nervous system, particularly in the spinal cord, and none of the methods of treatment hitherto discussed has any influence over it. Until its action is exhausted it continues to stimulate the motor, and, to a less degree the sensory, tracts of the spinal cord, and kills the patient by exhaustion.

We have at our disposal a number of drugs whose main therapeutic action is to render the spinal cord less susceptible to stimulus, and administration of one or more of these remedies forms an integral part of any rational plan for the treatment of tetanus. The drugs most often employed are chloral, chlorbutanol, and similar products, the bromids, magnesium sulphate, and of late years sodium persulphate. These drugs are to be administered until the therapeutic effect which is desired has been obtained. Ordinary doses are not sufficient, but it is quite possible to kill the patient by an overdose. In nine patients in my own series of cases (1912) the condition at death was noted. Only three patients died in spasm or convulsion, while six died in complete relaxation, and in some of these cases the condition was due to overdoses of the spinal depressants employed. Especially dangerous, I believe, is magnesium sulphate, which, as Bérard and Lumière³⁰ express it, is efficient only in *doses paramortelles*. I agree with them also that chloral, in doses of 4 to 10 gm daily, is the most efficient and inoffensive of spinal depressants, and I habitually employ it in conjunction with the bromids.

Their own experience³¹ with intravenous injections of sodium persulphate is worthy of great attention. Lumière employed it in eight cases before the war; only two of the patients died. During the war, he states that of twenty-nine patients treated efficiently by this method, only thirteen died, a mortality of 45 per cent. He injects intravenously once or twice daily 20 cc of a 5 per cent solution of the drug, which should be pure, and neutral in reaction. These injections are to be repeated daily or less often for the first or second week of the disease. But as Bérard and Lumière³⁰ themselves acknowledge, it is not so efficient in very acute cases, and chloral should be used also. They report a total of 116 cases which they treated during the war, with fifty-eight deaths, a mortality of 50 per cent. But it must be remembered that many of the war cases of tetanus were late, chronic, local or recurrent cases, and so the mortality cannot well be compared with that of the cases seen in civil life. Sodium persulphate should be preserved in solid form (dry!) in 5 gm quantities, in sealed tubes. The solutions can be preserved only a few days (not more than eight) and are decomposed by heat. They must be prepared fresh by dissolving the contents of the 5 gm tube in 100 cc of cold sterile distilled water. The solution corrodes metals, and metal syringes and needles must be very carefully washed after use. After the injection the clonic spasms cease, but the tonic spasm is unaffected. Vomiting occurs in about half the cases after the injection. He regards this remedy as antitoxic as well as depressant, and seems not to have employed any antitoxin in addition. Other authorities, however, doubt its antitoxic power.

30 Bérard and Lumière. *Presse med* 26 469 (Sept 12) 1918

31 Lumière. *Lyon chir* 12 411, 1915

TABLE 2—CASES OF TETANUS UNDER THE AUTHOR'S CARE

No	Date of Admission	Age and Sex	Site of Wound	Date and Nature of Injury	Incubation Time from Injury to Symptoms	Time from Symptoms to Institution of Efficient Treatment	Type of Case	Summary of Treatment		Result
								Original Injury	Tetanus	
1	9/23/08	34, M	Abdomen and thigh	Sept 24, 1908, brush burns, hematoma, thrown from wagon and dragged	14 days	1 hour	Slow in onset, but severe convulsions	Ordinary antiseptic	Sedatives, antitoxin subcutaneously (129,000 units) and intraspinally (3,000 units), total antitoxin, 132,000 units in 10 days	Recovered Oct 31, 1908
2	9/23/08	55, M	Cranium	Sept 23, 1908, gun shot fracture of temporal region and rupture of eye ball	4 weeks	12 hours	Mild, slow in onset, no convulsions	Aseptic no operation	Sedatives, antitoxin subcutaneously 31,500 units in 8 days	Recovered, eye ball enucleated Nov 17, 1908
3	11/12/08	49, M	Foot	Nov 4, 1908, punctured wound by rusty nail	8 days	24 hours	Medium severity, no convulsions	Home treatment by ham fat, etc	Sedatives; antitoxin intraspinally (3,000 units) and later subcutaneously (27,000 units), total amount, 30,000 units in 6 days	Recovered Nov 18, 1908
4	12/19/08	19, M	Foot	Nov 30, 1908, punctured wound by splinter from mill floor	18 days	24 hours	Severe convulsions before admission	Wound dressed twice but patient never returned for further dressings	Three splinters removed from wound, sedatives antitoxin intraspinally, 3,000 intravenously, 750 units, and into muscles around the wound, 750 units, total in 2 days, 4,500 units	Recovered Dec 31, 1908
5	10/10/09	63, M	Fingers	Sept 28, 1909, lacerations by machinery	18 days	24 hours	Severe no convulsions	Ordinary antiseptic dressings	Fingers amputated, sedatives (chlorbutanol antitoxin intraspinally 1,500 units	Died, Oct 19, 1909, after being comatose 24 hours
6	11/20/09	11, F	Knee	Nov 11, 1909 abrasion from fall	9 days	40 hours	Slow in onset, severe convulsions	Bread poultice at home	Sedatives (chlorbutanol), antitoxin intravenously 3 times, total 9,000 units intraspinally 1,500 units, subcutaneously, 3,500 units, total antitoxin, 13,500 units in 3 days	Died, Nov 22, 1909, after being comatose 3 hours
7	2/4/10	45, F	Toes	Jan 23, 1910, laceration, fall down stairs in bare feet	12 days	Few	Mild, slow onset no convulsions	Neglected for 10 days then iodine	Sedatives, antitoxin subcutaneously, 6,000 units in 3 days	Recovered Feb 10, 1910
8	2/21/10	23, F	Scalp	Jan 26, 1910, lacerated wound, hit by brick	19 days	1 week	Slow in onset, severe, no convulsions	Sutured, no drain	Abscess opened, sedatives, antitoxin intraspinally, 3,000 units, subcutaneously, 21,500 units total antitoxin, 24,500 units in 5 days	Recovered Mar 8, 1910
9	10/3/10	6, F	Arm	Sept 7, 1910, vaccination	Unknown less than 24 days	3 days	Slow onset, very severe, 2 convulsions every hour	Treated at home by mother	Sedatives, antitoxin intraspinally, 10,000 units (Oct 5), subcutaneously, 45,000 units, total antitoxin, 55,000 units in 2 days	Died, Oct 5 1910, in convulsion

11	11/20/13	23, M	Sole of right foot	Nov 12, 1913, puncture by rusty nail	7 days	9 days	Trismus first sign convulsions after admission	Untreated	Sedatives, antitoxin subcutaneously, 18,500 units intraspinally, 10,000 2d day, 9,000, 5th day, intravenously, 18,000 2d day, intravenously 5,000 5th day	Died Nov 25, 1913
12	10/20/15	17, F	Finger	Oct 15, 1915 puncture by machine needle in wooden mill	13 days	24 hours	Slow onset local pains for 5 days stiff neck for 1 day before admission	After 24 hours opened no antitoxin	Healed wound opened and cleaned, sedatives, large doses, antitoxin intraspinally, 10,000 units, intravenously 18,000 units, intramuscularly, 6,000 units	Recovered Nov 10 1915
13*	12/17/12	27, M	Right finger	Before Dec 1, 1912, crushed	9 days	9 days	Subacute onset, trismus, epigastriaic pain, stiff legs, spasm 3 days before treatment	Bandaged by patient	Sedatives, very large doses antitoxin intraspinally, 8,000 units, intravenously, 25,500 units	Recovered Dec 21, 1912, died Dec 22, 1912 of pneumonia
14*	4/11/14	58, M	Nose	April 7, 1914, struck by piece of bone in fertilizing plant	3 days	1 day	Severe, facial paralysis	Abscess formed and this was opened 4th day	Sedatives antitoxin intraspinally, 18,000 units in 2 days, intravenously 13,500 in 2 days into facial nerve, 1,500 on 2d day	Died April 13 1915, in coma
15*	11/17/14	18, M	Hand	Three weeks ago, scratch by wire nail	Over 2 weeks	5 days	Slow onset with stiffness and pains in legs trismus, spasms, opisthotonos and risus sar donicus on admission	Untreated	Sedatives, large doses, antitoxin intraspinally, 6,000 in travenously, 15,000, subcutaneously, 3,000 units	Recovered Dec 15, 1914
16*	10/20/15	34, F	Right knee	Oct 4, 1915, chafed in riding horseback	12 days	4 days	Subacute onset, pains in side, back muscles and neck, opisthotonos before treatment and constant spasms	Ointment applied by patient	Sedatives, very large doses antitoxin intraspinally, 9,000 units subcutaneously, 20,000 units in 6 days	Recovered Oct 20, 1915
17	10/20/16	32, M	Foot	Nov 16, 1916 puncture by rusty nail	8 days	2 days	Slow onset with stiffness of cheeks jaw and neck	Untreated	Sedatives intraspinally, 10,000 units, intravenously, 27,000 units in first 18 hours after admission	Recovered Dec 13, 1916
18	9/18/20	13, M	Feet?	?	?	5 days	Slow onset, tonic spasms on admission and opisthotonos	Untreated	Sedatives, intraspinally, 10,000 units, intravenously, 35,000 units in first 12 hours after admission	Recovered Oct 1, 1920

Spinal anesthesia is suggested by Bérard and Lumière and in one patient they secured marvellous relief from respiratory cramps by injecting a local anesthetic into both phrenic nerves at the root of the neck

D The patient, as well as the disease, must be treated, but it is perhaps unnecessary here to dwell further on nursing, feeding, and meeting every untoward symptom as it arises

I have had under my personal observation eighteen cases of tetanus, all in civil life, seven of these patients died (38·8 per cent), one of them (Case 13 in Table 2) from pneumonia, after apparent recovery from the tetanus. In three other fatal cases, treatment was neither early nor efficient enough to be successful (Cases 6, 9 and 11), while the death of one patient (Case 10) was clearly due to an overdose of magnesium sulphate intraspinally. This leaves thirteen cases in which treatment may be regarded as early and efficient, among these, only two patients died, a mortality of 15·38 per cent

D *Summary*—My views as to the treatment of tetanus may be summarized by narrating the history of the next to the last patient to come under my care. He was treated early and efficiently, and recovered

CASE 17—*History*—M. H. J., aged 32, a member of one of the faculties in the University of Pennsylvania, referred to me by Dr Alfred Stengel, was seen in my office about 7 p. m., Nov. 26, 1916. He stated that two days before (Nov. 24, 1916) he noted in the morning that his cheeks felt stiff, as if he had been out in the wind all day (which he had not). The next day he felt the same way, and on the morning of the 26th he noticed in addition to the sensation of stiffness in the cheeks and jaw, that he was stiff in the neck and shoulders, as if from overexercise. Only then did he recollect that on November 16 or 17, while doing some carpenter work in his garden, he had stepped on a rusty nail, which had perforated his shoe and penetrated his foot from 2·5 to 3 cm. He had extracted the nail, squeezed out a few drops of blood, and the puncture had given no further trouble. He had forgotten about it until the persistence of stiffness in the jaws and neck made him apprehensive of the development of tetanus.

Examination—This was negative, except for slight stiffness in the jaws, but the mouth could be opened well. Nevertheless, the sensation of stiffness was pronounced in the jaws, neck and shoulders.

Clinical Course—I took him with me at once to the Episcopal Hospital, and as he rode beside me in the car I felt anxious lest he should suddenly grow worse and have a convulsion. There seemed no doubt about the diagnosis. If delay were allowed, the treatment, no matter how energetic, would come too late to be efficient.

By 8 p. m. (one hour after he came to my notice), this patient had received, under local anesthesia, 10,000 units of concentrated antitoxin intraspinally by lumbar puncture. (The cerebrospinal fluid withdrawn was reported by Dr C. Y. White as containing no cells, and when injected into a mouse, it had no deleterious effect.) The puncture in his foot could not be certainly identified, and nothing was done to it. He received also, by mouth, chloral hydrate,

1 gm, and sodium bromid, 2 gm By 12 midnight his temperature had risen to 39 C (102.2 F) but had fallen again to 37.8 C (100 F) by morning

Nov 27, 1916 The patient was delirious, muttered under his breath, and was so restless that restraint was necessary His jaws were firmly locked, but with effort could be opened slightly The neck was stiff, but there was no opisthotonos Knee jerks were increased on both sides, there was a slight Babinski reflex on the left side He was given 27,000 units of antitoxin (diluted in saline solution) intravenously, and following this, he had a severe chill and his temperature rose to 40 C (104 F) Immediately thereafter it fell to 37 C (98.6 F) and never rose subsequently above 37.8 C (100 F) He was given chloral hydrate, 2 gm, and sodium bromid, 4 gm, every three hours by rectum, as he could not swallow About 6 p m, the patient began to clear up mentally His neck continued very stiff At 7.30 p m he was given two drops of oleum tigli (Croton oil) He voided 830 cc of urine during the day

Nov 28, 1916 The patient was improving, the knee jerks were increased, there was a slight Babinski reflex on both sides The head could be flexed beyond the plane of the body, the neck being quite rigid There was some headache The bowels were opened twice He voided 800 cc of urine Chloral and bromid were given as on the preceding day

Nov 29, 1916 He lay on his side curled up, and slept most of the time He took nourishment well There was some headache The neck was slightly stiff still Chloral and bromids were given only in one third the former dose, and by mouth

Dec 1, 1916 Urticarial rash appeared over the whole body Itching was relieved by phenolated petrolatum

Dec 2, 1916 Urticarial rash was more pronounced This was relieved by 5 drops of pituitary extract He was nauseated, but was relieved by vomiting

Dec 13, 1916 Convalescence was uneventful He went home today

RIB GRAFTING OPERATIONS FOR THE REPAIR OF BONE DEFECTS AND THEIR END-RESULTS

AT LETTERMAN GENERAL HOSPITAL *

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Of late it seems as though a few definite conclusions may have been reached as to the growth of bone. Gallie and Robertson,¹ Hey-Groves² and others have presented the results of many years of research in scores of laboratories and have outlined the theories deduced in admirably clear papers.

Opinions as to the proper way of performing a bone grafting operation still seem, however, to be diametrically opposed. In this country we are led by Albee's energetic advocacy of the massive transplant. The French, as far as I can judge, follow Delagenière's method of thin, periosteal-osteal flaps. The English, if I interpret Sir Robert Jones' expressions of opinion correctly, regard the bone graft with considerable distrust and put their faith in shortening and suturing ununited fractures. In order, then, to arrive at an estimate of the value of bone grafts, and at a conclusion regarding the proper method of performing them, it would seem worth while for each man to gather his results and review them as honestly as possible. It might be even fairer to appoint an impartial commission—if there is such a thing—to conduct the inquiry.

I wish to present a series of cases in which one particular method of grafting was employed. The series is small, but I have tried to judge the results as impartially as possible. I have tried to follow the patients, soldiers at Letterman General Hospital, after their return to civil life and to find out, as best I could, the functional value of the grafted bone. In presenting the series I am making no plea for the method I have followed.

It has not been easy to arrive at a just basis for judgment. Roentgen rays give objective and impersonal evidence, but they are

* Read before the Section on Orthopedic Surgery at the Seventy-First Annual Session of the American Medical Association, New Orleans, April, 1920.

1 Gallie, W. E., and Robertson, D. E. The Repair of Bone, *Brit J Surg* 7: 211 (Oct.) 1919.

2 Hey-Groves, E. W. Methods and Results of Transplantation of Bone in the Repair of Defects Caused by Injury or Disease, *Brit J Surg* 5: 185 (Oct.) 1917.

notoriously fallacious guides to function. On the other hand, wage-earning capacity and even the extremities themselves are often faulty indexes of the value of a graft. Bony defects resulting from battle wounds are so frequently accompanied by grave nerve lesions and extensive loss of muscles and tendons that the extremity remains quite useless, even with the most perfectly repaired bone.

It might be best to eliminate from the statistics of bone grafting operations all cases in which there were grave nerve lesions or extensive injuries of the soft parts. This, however, would reduce the series by two-thirds or more. The better plan will be, I suppose, to combine roentgen-ray evidence with estimates of the actual functional value of the extremity.

The rib was chosen as a source of supply for the graft for several reasons, theoretical and practical.

THEORETICAL ADVANTAGES OF RIB GRAFT

In theory it was argued that most, if not quite all, of the osseous part of the graft dies, and that only its osteoblastic elements (both the epistéal osteoblasts and the osteoblasts lying at the mouths of open haversian canals) survive. It was argued that experiments have shown that the more accessible these viable osteoblastic elements of the graft are to the nutrient juices of the body, the sooner does their proliferation begin, furthermore, it was thought that of the transplanted osseous tissue only those minute portions which lay immediately under the periosteum, and along the endosteum of the cancellous portions, survive, i. e., again those portions which are most readily accessible to the nutrient juices. If this be true, the viability of the graft would be in inverse proportion to its mass. Thick, poorly permeable pieces of bone die off more slowly, and the processes of absorption and restitution are more tardy, more permeable pieces, of greater surface area and less cubic content, are attacked and restored more quickly. It was, therefore, reasoned that a graft with a thin, vascular, soft cortex and a large proportion of cancellous marrow spaces would be better than one with a thick, dense cortex and little or no cancellous tissue. It was thought that the inevitable absorption of osseous tissue would take place more quickly in the thin graft than in the thick one, that deposits of permanent bone would be laid down more rapidly and that the graft might be sooner put to use and submitted to the forces which cause active functional hypertrophy.

Whether or not these theoretical premises have been borne out by practice I am not prepared to say. I am inclined to doubt it.

Gallie had not published the outcome of his investigations at the time these operations were undertaken. His observations seem to

show that the processes of absorption outstrip those of replacement. He says that after the lapse of five weeks the graft is exceedingly porous and fragile, and that it remains so until the irritation from the presence of dead bone disappears, i. e., after eight or nine weeks. He states that the longer the gap, the thicker the graft used to fill it should be, so that it may retain strength during the stage of osteoporosis and that, although a porous bone graft retains more cellular activity than a massive one, it has also a much greater tendency to rapid absorption and must be used with care. Hence, he warns against the use of cancellous bone, such as the rib, when the graft is to be put under strain, and prefers a strong piece of tibia surrounded by a number of smaller strips, the latter to facilitate the access of an increased number of osteoblasts.

The series under consideration would tend to show that Gallie is right, that the very tardiness with which the more massive grafts are absorbed may be of advantage, and that they offer firm mechanical support for a longer period. Once the invading capillaries have started their work of absorption and replacement, there may be more new bone laid down in the dense substance of a massive graft than in the frailer body of a thin one, which is probably so rapidly swept away that its trellis is gone by the time the osteoblasts are ready to lay their bony deposits on it. I shall refer to this question again in considering the frequency of fractures of grafts. Clinical observation must settle this point, laboratory experiments can scarcely help us.

The rib, then, was chosen on theoretical grounds in preference to the tibia because it was softer and more easily permeable. It seemed that more of it might live and that what was doomed to die would be absorbed and replaced more quickly. It was chosen in preference to the osteoperiosteal transplant of Delageniere—a free graft of periosteal membrane with a few bone chips clinging to its under surface—because it was not so utterly flimsy and because, while it was not so strong as a tibial graft, it had some substance and some strength. It was, therefore, not necessary to place entire reliance on casts and other external means of fixation and support.

PRACTICAL ADVANTAGES OF RIB GRAFTS

Aside from the theoretical, the rib graft offers a number of practical advantages. No special instrumentarium is required for the operation. This is of minor importance. Letterman General Hospital is equipped with the Albee outfit, and so are most institutions where bone grafting operations are performed. At any rate, if they are not properly equipped, they should be. However, the Albee outfit does break down now and then, often at the particular moment when

it is most needed, and it is a reassuring feeling, when undertaking an operation, to know that one is not entirely at the mercy of an electric saw

The rib is much more workable than the tibia. It can be bent or cut into the desired shape with bone-cutting forceps or a stout pair of scissors. It can be pierced with a stout needle. It has more spring and is not so liable to crack as the tibia. And in spite of its lightness, it is quite strong, strong enough to give good support to the lighter bones, especially the radius and ulna. Its strength lies in its curved cross-section, just as weight for weight a tube is stronger than a solid cylinder, or a piece of channel iron is stronger than a sheet of the same metal. When the rib is split in halves longitudinally, it forms a stout trough that can be wrapped about half the circumference of one of the smaller bones so as to hold it firmly in position. Again, the rib can be split into staves, with which two fragments may be firmly surrounded and effectually splinted. It makes an excellent, pliable, workable internal splinting material.

The supply is practically unlimited. To take 6 inches or so from one or two of the ribs does not affect the well-being of the patient.

The operation does not entail a lengthy stay in bed, nor does it keep the patient off his feet for more than a few days, a week at most. Many patients on whom bone grafting operations are indicated have been so long bedridden that they dread the prospect of an additional six or eight weeks in bed on account of a weak tibia.

The operation itself is neither more difficult nor more dangerous, nor does it take longer to resect a piece of rib than to saw a piece out of the tibia.

The sterility of the operative field is always more or less a matter of doubt in bone defects due to war injuries. In these dubiously aseptic cases, the less massive and more viable rib graft has a greater chance of weathering an infection than a heavy tibial graft. The graft acts for the first few days much like a foreign body. The less dead material one implants the less the risk of lighting up dormant infections. The rib, therefore, has many practical advantages over the tibia.

I am quite willing, however, to concede that all of these advantages may be more than offset if statistics of end-results show that the graft from the rib is not as good as that from the tibia.

TECHNIC OF RIB GRAFTING

The technic of rib grafting is not difficult. The bed is prepared as for any other graft. It must contain no sequestrums buried in dormant pus. The wound should be healed, if possible. The scar

should be reactionless and able to withstand heavy massage without breaking down. If it is adherent to the bone it should be excised, preferably at a preliminary operation, and the site prepared for the graft should be covered by healthy skin. If it is not possible to mobilize the wound edges sufficiently to cover the bone with nonadherent skin, sound skin and subcutaneous fat should be brought down from elsewhere, either as a pedunculated flap or as an Italian graft.

The field should be prepared antiseptically and aseptically forty-eight hours before operation.

The extremity should be made bloodless with a tourniquet and the bones exposed through a generous incision. Sclerosed and eburnated bone should be removed from the ends of the fragments and the fragments brought into proper line by traction and by the excision of distorting scars if necessary. A hole should be bored through the end of each fragment, and a stout kangaroo tendon threaded through it. A hot compress is placed in the wound, the tourniquet removed, and bleeding stopped. One bloodsoaked compress should be saved to wrap the graft in. The patient's own blood is probably the best and certainly the most natural medium in which to keep the graft. An incision is made over the fifth or sixth rib, beginning at the costochondral junction, i. e., about half way between the nipple and sternum and extending backward far enough to expose the required amount of bone. The front part of the fifth or sixth rib is usually chosen because it is straightest. For a curved graft, to be placed in the jaw or skull, the surgeon should select a lower rib, which is more curved, and take the piece farther back. In women, the sixth or seventh rib may be used so that the incision may follow the lower border of the breast. The breast may be lifted up and a piece of rib taken from beneath it. Grafts for the repair of nasal defects may be taken from the costochondral junction, including both bone and cartilage.

The one difficult step in the operation is getting the rib out together with the periosteum without opening the pleura. Entering the chest does no serious harm, but it had better be avoided. The pleura was opened seven times in this series without noticeable effect except in one patient in whom a subcutaneous emphysema developed which persisted a few days. If the chest is opened, the opening should be stopped with a large moist compress while the rib is being resected, so as to prevent the lung from flapping about in the gaping pneumothorax.

A sufficient length of rib is exposed, and the muscle, the serratus magnus, retracted. The attachment of the external intercostal muscle is severed with a knife. The muscle fibers slant from above and behind downward and forward. The knife should therefore pass forward along the upper edge of the rib and backward along the

lower edge If passed in this direction, it remains in the angle made by the muscle fibers and the rib The rib should first be cleared of its muscular attachments for an inch or two in front The knife should be used very carefully and delicately until the pleura comes to view and the speckled tissue of the lung is seen sliding back and forth under it After an inch or two of the rib is clear the pleura may be very gently pushed away from it with the handle of the knife or some other blunt instrument The rib must be freed from the intercostal muscles with a knife Blunt dissection, either with gauze or with an instrument, will not separate the costal periosteum from the pleura A healthy pleura is as thin as tissue paper It will inevitably tear if a blunt instrument is used in an attempt to strip the periosteum of the rib from it The minutest hole is irreparable Once punctured, the pleura always tears farther If, however, the intercostal muscles are cut away from the rib for an inch or two in the manner described, they may be gently pushed off the pleura and the pleura separated from behind the rib When the inner surface of the rib is free, curved rib shears may be inserted and the front end of the graft cut through If the rib is then forcibly retracted outward, it is easy to cut away the intercostal muscular attachments as far back as is necessary The pleura drops away from the rib by its own tension so that there is little danger of entering the chest

Six or more inches of bone may be obtained without difficulty

There is no danger of wounding the intercostal artery if the front of the rib is cleared first and if the knife hugs the bone closely The artery comes out from under the edge of the rib between the two axillary lines If it is exposed before the axilla is reached, it is easily avoided If it is wounded, bleeding should be stopped by pressure until the rib is removed Blind attempts at grasping the artery with a hemostat endanger the pleura The artery should, however, be exposed and securely tied before suturing the wound, especially if the pleura is open, so that there may not be bleeding into the pleural cavity

No attempt should be made to suture the pleura separately if it has been opened The hole should be stopped with a compress while the muscles are being sutured together It is well to take the last stitch during expiration so as to get as much air out of the chest as possible before closing it

The wound in the chest is closed by an assistant while the operator prepares the graft He drills a hole for the kangaroo tendon suture through each end of the excised piece of rib If the ends of the fracture are to be separated, the distance between the holes in the graft should exceed the distance between the holes through the fragments After the holes have been drilled, the lower edge of the graft is split longitudinally with an osteotome or a stout knife and the rib opened

out like an oyster, a hinge of periosteum remaining along the upper border. The rib is pliable enough to be straightened out somewhat with the hand if it is too curved, although it tends to spring back into its original shape. The kangaroo tendon sutures are threaded through the holes in the graft and the fracture ends laid into the trough formed by the split rib. Both ends of each suture are passed under the bone with a ligature carrier and the suture is firmly tied about the whole graft and the bone. If the fragments tend to move in the trough, a second ligature may be passed either above or below the first. This may either be led through drill holes or simply wrapped about both graft and

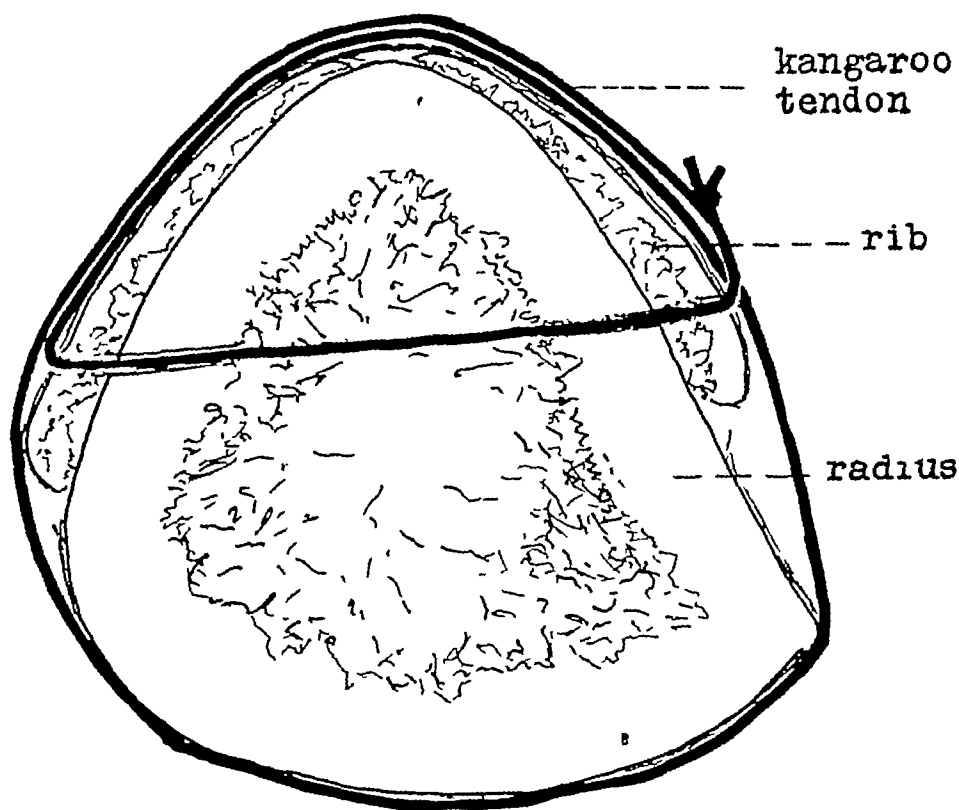


Fig 1—Cross-section of radius and rib graft. The rib is split longitudinally, its two halves are joined above by a periosteal hinge. Kangaroo tendon passes through drill holes and encircles both rib and radius.

fragment. The periosteum of the bone is sutured as well as may be about the rib, the soft parts are brought together accurately, the wound is closed, and the extremity is encased in plaster.

Variations applicable to different types of cases will suggest themselves. In a large defect of the humerus, two ribs were taken, split in halves, and the fragments wrapped about the two ends of the humerus like barrel staves. The space between the staves was sprinkled with iodoform powder and left to fill with blood-clot. An

artificial marrow cavity was made. The result was unsuccessful. The defect was bridged and the graft united, but the arm was subsequently refractured. There is still nonunion. The arm is not nearly so flail as it was. There is some power, but the union is by no means firm (Fig 27).

The rib graft is particularly useful when sepsis makes the success of a more massive transplant unlikely. In one patient, with a tibial defect, a rib graft was used successfully while the wound was still open. There was a large scar over the front of the shin, extending down through the defect, and in its middle a granulating area about half a centimeter in diameter. An Italian plastic operation to cover the defect was thought inadvisable because of recent attacks of streptococcic infection. An attempt to unite the fibula (which was intact) with the tibial fragments, a procedure which entails considerable manipulative trauma, was thought inadvisable for the same reason, and I was loath to risk the stability of the one remaining bone of the leg on so slender a prospect of success. An incision was therefore made on the inner posterior side of the leg, the side farthest from the scar, and the back of the tibia exposed without disturbing much of the fibrous tissue lying between the bone ends. A piece of rib 5 inches long was split in two longitudinally and each half laid against the back of the tibia, spanning the defect. The wound was closed loosely and the leg put in a splint. The man had some fever following the operation, but none of the graft came out, the fracture united, and the man can support his whole weight on the leg, although he still wears a brace for a foot-drop due to destruction of the extensor muscles (Fig 22).

The rib is particularly well adapted for filling in cranial defects. The convexity fits in well with the curve of the cranium and gives an excellent cosmetic result.

I think that I have erred in the after-treatment of these patients in not fixing their limbs sufficiently firmly or sufficiently long. A number of them were fixed in splints instead of in circular casts. Most of the casts were removed too soon. Had I to do them over again I should, in the light of Gallie and Robertson's experiments, apply circular plaster dressings and leave these on at least two months.

The question when to take off the cast, when to leave off all support, and when to begin active motion and use, should be determined by information as to the time when absorption of the transplant ceases, when hypertrophy begins, and when the bone reaches its maximum size—not density, but size. Gallie's experiments show that absorption is complete at the end of two months. Fixation therefore, should somewhat exceed this period, and plaster should be used

for ten or twelve weeks. Rib grafts take several months before they begin to show roentgenographic evidences of growth, but that they finally do grow and become stronger may be seen in a number of roentgenograms.

END-RESULTS

I have tried to follow as many of the patients as I could up to and after their discharge, and I have tried to judge honestly of their condition. As I said in the beginning, I scarcely know what to call a success and what a failure. Is the operation a success in a man with a radius which is firm clinically and according to roentgen-ray findings, but with a median and ulnar palsy and the remains of an ischemic contracture, with a stiff claw hand? And is the operation on the radius of a man whose roentgenogram reveals a fractured graft, but who can hold a chair out at arm's length, a failure? I shall call those operations failures which result clinically in nonunion and flail extremities, I shall call those operations partial successes when there is roentgenographic evidence of refracture or bone absorption, but in which the extremities are useful clinically. I shall call those operations successes in which both roentgen-ray and clinical observation indicate firm union.

The series includes twenty-two patients operated on at Letterman General Hospital from January to October, 1919. One attempt at replacing the carpals in a flail wrist by a free rib graft was accompanied by suppuration and was a failure. There are ten defects of the radius alone, seven successes and three partial successes. There is one defect of the ulna alone, a partial success, refractured at operation. There are five defects of both radius and ulna, one partial success and four successes. There are three defects of the humerus, all failures. In the man shown in Figure 27 the large defect is repaired, but there are a refracture and nonunion. There is one defect of the tibia and one of the jaw, both of which were successfully repaired. Eleven of the men had more or less suppuration following operation, in some of them the suppuration came on late, sometimes a number of weeks after operation. In but one case what apparently was the entire graft was lost. This occurred in a fracture of the humerus. Others healed spontaneously without sequestration.

Refracture occurred in seven, almost one third, of the twenty-two cases.³ The graft always broke near the middle, the ends being united to the matrix bone. That these fractures occurred at the middle of the grafts while the ends remained firmly welded to the ends of the main fragments shows the truth of Gallie's statements that the proc-

3 Figures 4, 14, 15, 18B, 26 and 28. Compare with accompanying table.

esses of absorption outstrip those of replacement, and that the ingrowth of bone occurs largely through the migration of bone cells from the neighboring bony bed rather than by proliferation of the osteogenic tissue of the graft itself

The ends of the graft, those nearest the source of living bone supply, showed no atrophy, they remained firm and dense. It was the middle of the graft, the part most distant from the bone of the host, that was thinnest and that gave way most easily under strain. Most of these refractures have remained ununited so far as I have been able to follow them. In two of them, however, the refracture united, in one with considerable callus. These cases, a parallel to those cited by Hey-Groves,² prove that the grafts were alive (or had been supplanted by living bone cells) and that their bone had powers of osteogenesis (Figs 23 B, 23 C and 24). It is true that two of the seven were firm but were refractured after operations in which much bone was removed. It is also true that most of the fractured ones were not splinted with a view to obtaining reunion. Still, refracture of the graft occurs so frequently that it makes me look askance at the rib graft for the repair of defects that put the implanted bone under much strain.

CONCLUSIONS

- 1 The rib graft is a feasible procedure
- 2 The viability of the grafts is great, even in the presence of supuration
- 3 They are more apt to survive in the presence of infection than more massive grafts
- 4 They are rapidly absorbed
- 5 They hypertrophy slowly
- 6 They are prone to refracture (seven out of twenty-two cases)
- 7 They are not so good as tibial grafts for the repair of large defects or when the graft is to be put under strain
- 8 They are particularly useful when no great demands are made on the strength of the bone, in repairing defects of the skull and in facial plastics. In such cases they should be used by preference
- 9 Of a series of twenty-two cases, three were failures, thirteen were successes and six were partial successes

REPORT OF CASES

CASE 1—A O, Pvt Co G, 18th Inf, aged 28. High explosive wound of left wrist, May 4, 1917. Entered Letterman General Hospital Sept 26 1918. Fract left wrist. Distal end of radius and ulna, and all carpal bones except trapezium are missing. Hand deviates to ulnar side.

Feb 3, 1919 Rib graft to take place of missing carpal bones and to correct ulnar deviation of hand Graft inserted into a newly formed joint cavity with a true synovial lining Periosteum scraped off one side of one of the grafts, and distal end of radius freshened to bring graft into connection with it Wound closed Splint applied Pleural cavity was opened

February 5 Emphysema of chest wall and neck noted Temperature increasing to 102.8, February 7 Part of graft removed Pus present

February 26 Remainder of graft extruded May 2, 1919 Discharged Civil disability $\frac{1}{2}$ Flail wrist and wearing wristlet at time of discharge

Failure on account of suppuration Roentgenograms lost

CASE 2—A A, Pvt, Co C, 3d Army M P, aged 30 Pistol wound, June 16, 1919, entered Letterman General Hospital, Aug 18, 1919 Compound comminuted fracture of middle and lower third of right radius Longitudinal defect Nonunion

August 26 Rib graft Muscular interposition Three inches of rib tied around fracture Pleural cavity not opened

October 31 Cast removed and reapplied

December 4 Cast removed Union

Dec. 27, 1919 Discharged to full duty

Complete success Roentgenograms lost

CASE 3—B T P, Pvt, M G B, 362d Inf, aged 27, machine gun bullet wound of left forearm, received Sept 29, 1918, entered Letterman General Hospital, July 3, 1919 Wound healed Ununited fracture of left ulna in upper third with two-inch defect

July 10 Rib graft Six inches of rib split and fragments of ulna fixed in trough Pleura not opened

July 18 Sutures removed Wound looks healthy

July 26 Pus found in dressings

October 6 Roentgenogram showing condition of graft (Fig 2A)

November 17 Sequestrums removed

November 26 Roentgenogram (Fig 2 B)

December 15 Beginning union Slight discharge

Jan 15, 1920 Roentgenogram (Fig 2C)

Jan 30 Sequestrums removed Incision packed Enough callus for union

February 25 Superficially granulating shallow scar and thick callus noted Patient has good grip Good union

April 14 Since this date patient was reoperated on Graft refractured during operation

Partial success Roentgenograms reveal progressive increase in density of callus

CASE 4—B P, Cpl, Co K, 9th Inf, aged 21, high explosive wound received June 29, 1918 Compound comminuted fracture of both bones of left forearm, upper third Thomas splint applied Balkan frame used for one and one-half months Following this, osteotomy was performed for malposition Nonunion Infection occurred at a second operation Entered Letterman General Hospital, Dec 19, 1918 Flail arm 3 inches below elbow Nonunion of both bones

Jan 21, 1919 Mortising operation Silver wire passed through drill hole Primary union of skin incision

March 1 Nonunion

May 6 Second mortising operation Nonunion

July 25 Roentgenogram no callus Separation of fragments of radius Ulna in fair line, but no callus formation (Fig 3A)

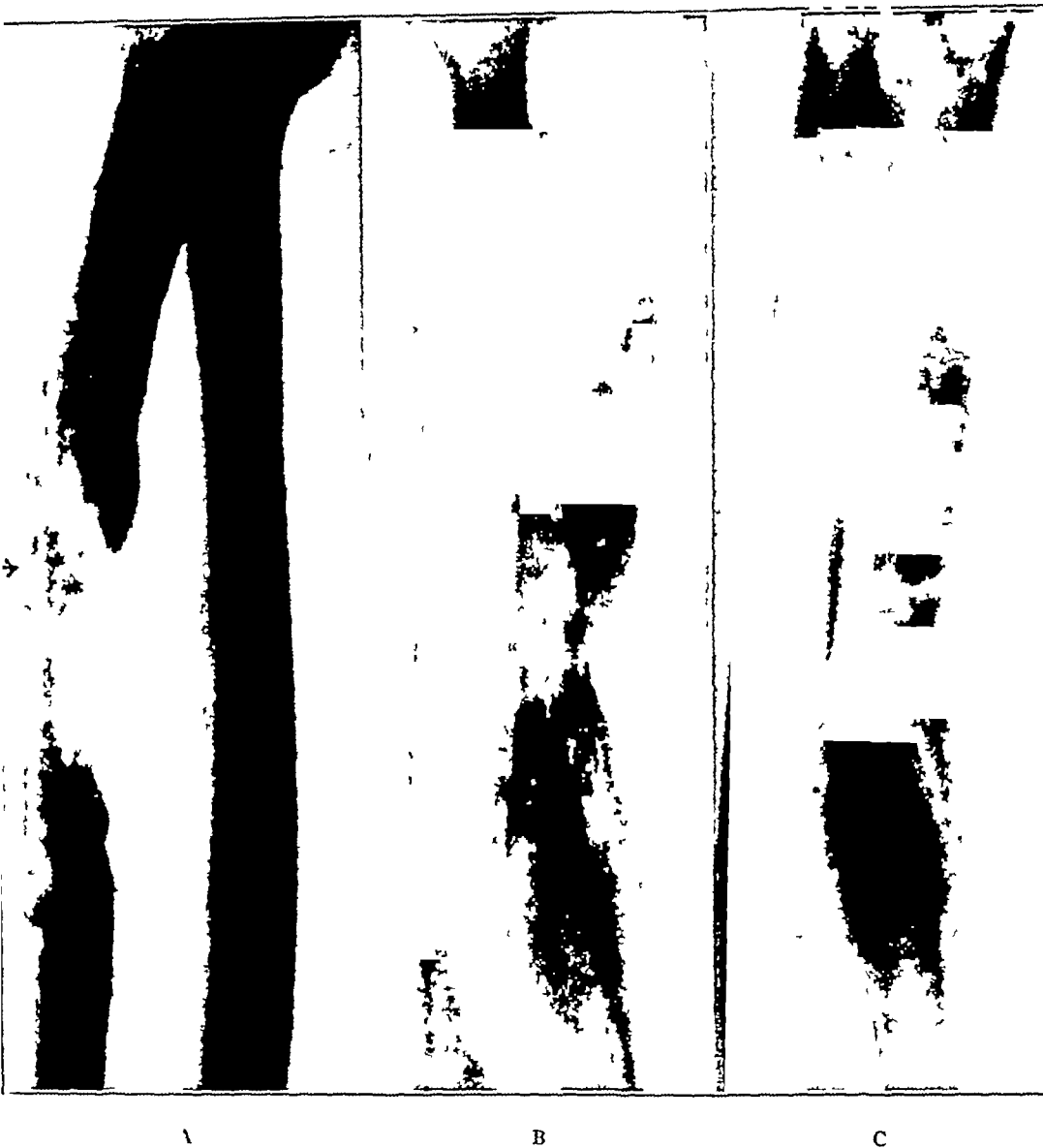


Fig 2 (Case 3) — *A*, three months after operation arrow points to graft with sequestrums *B*, four months and fourteen days after operation Firm union and hypertrophy of ends of graft. Osteomyelitis and sequestrum at middle of graft *C*, six months after operation Firm union Refracture occurred later at a reoperation for osteomyelitic sinus

August 5 Third operation Rib graft inserted Rib split into halves Each half chiseled in two diagonally Four resulting fragments tied around radius and ulna Pleura opened during removal of ribs

October 10 Cast removed Fracture firm Small pressure sore over graft Otherwise primary union

Jan 8, 1920 Roentgenogram (Fig 3 B)

Jan 16, 1920 Discharged (1) shortening of left radius and ulna, (2) incomplete flexion of phalanges Civil disability (1) $\frac{1}{12}$, (2) $\frac{1}{24}$

April 6 Good strength in arm, almost as good as the other Full extension Flexion to 35 degrees Full pronation Supination 120 degrees, 60 de-



A

B

Fig 3 (Case 4)—A, before rib grafting operation B, five months after operation Firm union Good alignment

grees less than on the normal side Good grip Wounds firmly healed Bones firmly united

Complete success

CASE 5—C C, Pfc, Co I, 361st Inf, aged 24, Sept 27, 1918, machine gun bullet wound of right humerus, entered Letterman General Hospital, May 15, 1919 Nonunion of the lower end right humerus with a 2 inch defect Musculospiral palsy is present

May 24 First operation Bone freshened and sutured with kangaroo tendon Musculospiral nerve also sutured

Nonunion

August 12 Rib graft inserted Four and one-half inches of rib split longitudinally and then diagonally Three of these four pieces were fastened around humerus with kangaroo tendon Pleura opened during operation Dec 28 Roentgenogram (Fig 4)

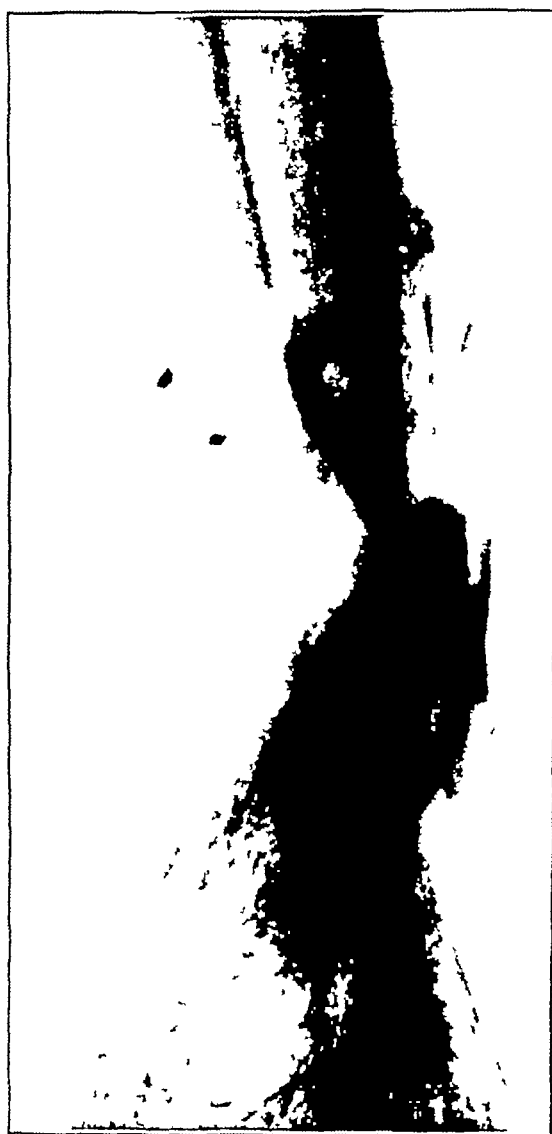


Fig 4 (Case 5)—Four months and two weeks after operation Union of grafts at each end, fracture (absorption?) of middle Nonunion

October 14 Cast removed Nonunion

Jan 19, 1920 Discharged (1) musculospiral palsy, (2) humerus is ununited
Civil disability (1) $\frac{1}{4}$, (2) $\frac{1}{4}$

April 3 Writes that condition is unchanged

Failure was due to suppuration and absorption of the graft

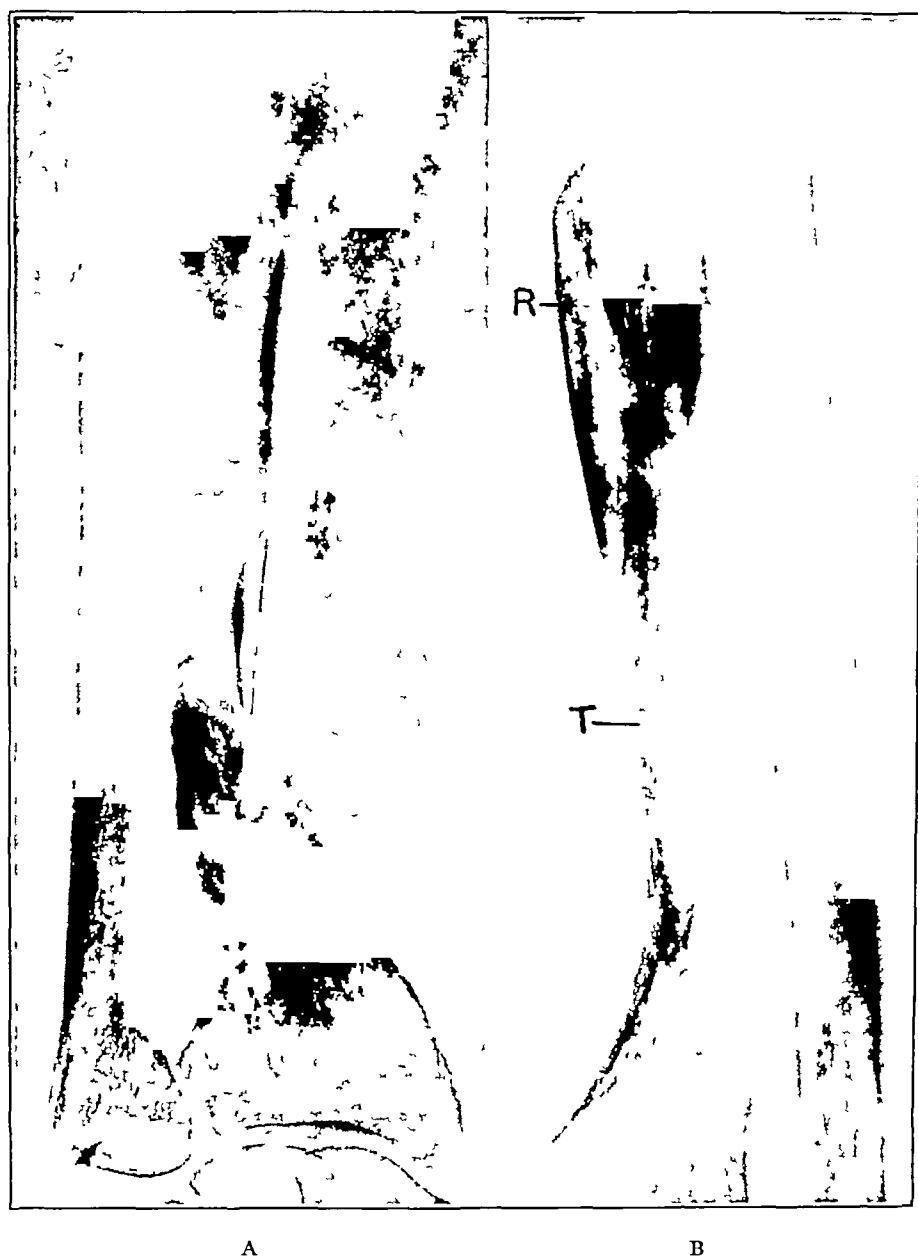


Fig 5 (Case 6) —*A*, twenty-six days after tibial graft. Upper end of graft has slipped. Nonunion. *B*, five months and nineteen days after tibial graft, two months and twenty-two days after rib graft, *R*, rib graft, *T*, tibial graft.

CASE 6—D I, Pvt, Co C, 362d Inf, aged 28, Sept 29, 1918, high explosive wound of left forearm Considerable part of radius removed at Evacuation Hospital No 10

Jan 7, 1919 Letterman General Hospital Eight cm defect middle and lower third left radius

Feb 6 Albee graft from tibia Distal end wedged into crack Proximal end fastened to proximal fragment with catgut Nonunion proximal end

March 3 Roentgenogram (Fig 5 A)

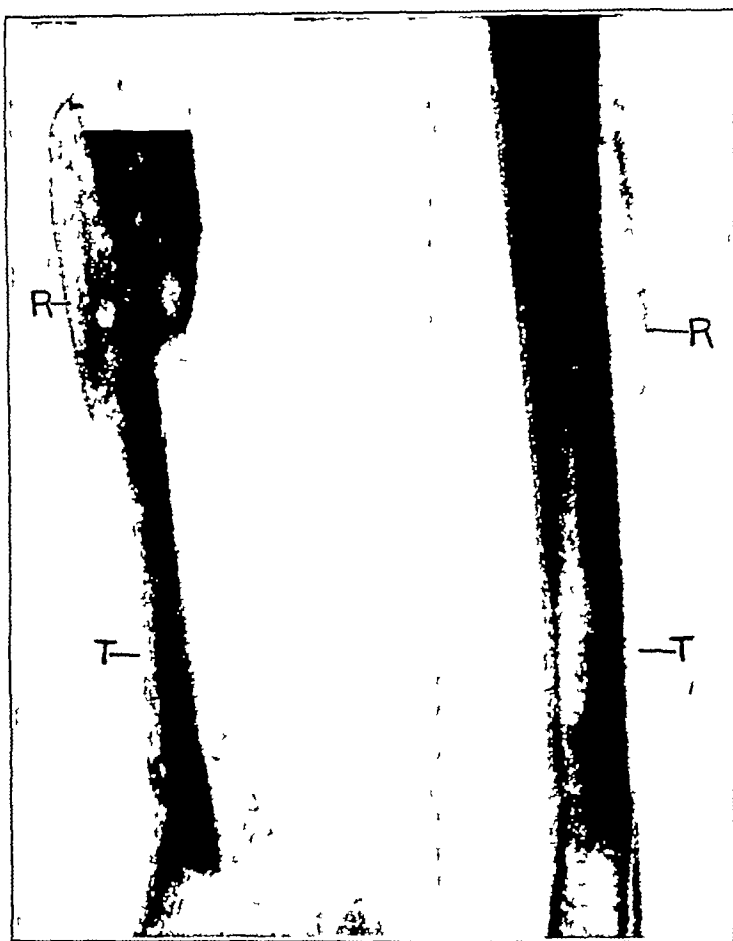


Fig 6 (Case 6)—Seven months after tibial graft, four months, fourteen days after rib graft Firm union of both rib and tibial implants to each other and to matrix bone of radius Good alignment R, rib graft, T, tibial graft

May 3 Rib graft Former Albee graft alive Distal end firmly united Proximal end lies against radius, separated from it by thin scar Three inches of sixth rib removed Rib split Distal end of proximal fragment of radius and proximal end of graft tied into the rib Pleura not opened

July 25 Roentgenogram (Fig 5 B)

Aug 1 Wound healed, perfectly firm

Sept 17 Roentgenogram (Fig 6)

Sept 18 Discharged Ankylosis (partial), left wrist Contracture flexor muscles fingers of left hand Civil disability $\frac{1}{3}$

Complete success Union of second graft to first Roentgenograms reveal progressive hypertrophy

CASE 7—D J S, Pvt, Co N, 110th Inf, aged 23, Sept 4, 1918, received machine gun bullet wound of left forearm, the lower third of the radius being fractured

Dec 19, 1918 Entered Letterman General Hospital Healing scars noted on left forearm Nonunion left radius with a defect of from 2 to 3 cm

Feb 2, 1919 Arm suspended by thumb to correct ulnar deviation of hand



A

B

C

Fig 7 (Case 7)—*A*, twenty-eight days after first operation—chip graft Before rib grafting operation *B* and *C*, two months after rib graft operation Firm union of rib graft Former chip graft still in place under rib graft *R*, rib graft, *Ch*, chip graft

February 6 Operation Graft $1\frac{1}{2}$ inches long, $\frac{1}{2}$ inch thick, chiseled off outside of radius One end sharpened into a wedge and forced into a crack made in distal fragment with chisel Other end laid against upper fragment No retaining suture Wound healed by first intention

March 6 Roentgenogram (Fig 7 *A*)

May 17 Nonunion Rib graft Previous graft separated from each end of radius by scar Graft is alive Three and one-half inches of sixth rib removed, split, and tied over fragments of radius Pleura opened during operation

July 19 Roentgenogram (Fig 7 *B* and *C*)

September 4 Firm union Discharged Synostosis (partial) between lower end radius and ulna Ankylosis (partial) metacarpophalangeal joint first finger left Civil disability $\frac{1}{8}$

Complete success



Fig 8 (Case 8)—*A*, three months, nine days after operation Good alignment *B*, five months after operation Firm union Good callus at end of graft Good alignment Increase in density of graft Compare with *A*

CASE 8—E R C, Pvt, Co C, 59th Inf, aged 28, Oct 12, 1918, high explosive wound, right forearm Two sequestrotomies (February and March, 1919)



Fig 9 (Case 8) —Six and one-half months' after rib graft One and one-half months after reoperation at which a piece of graft was removed and the incision packed Beginning atrophy of graft Compare with Figure 8 Refracture occurred at a later operation

June 22, 1919 Entered Letterman General Hospital Two inch defect, lower fourth of right radius present Paralysis (partial) right median, ulnar and radial nerves

July 29 Rib graft Five inches of rib split and tied about each end of bone

Aug 16 Wound suppurating Wound dressed daily

Nov 7 Roentgenogram (Fig 8 A)

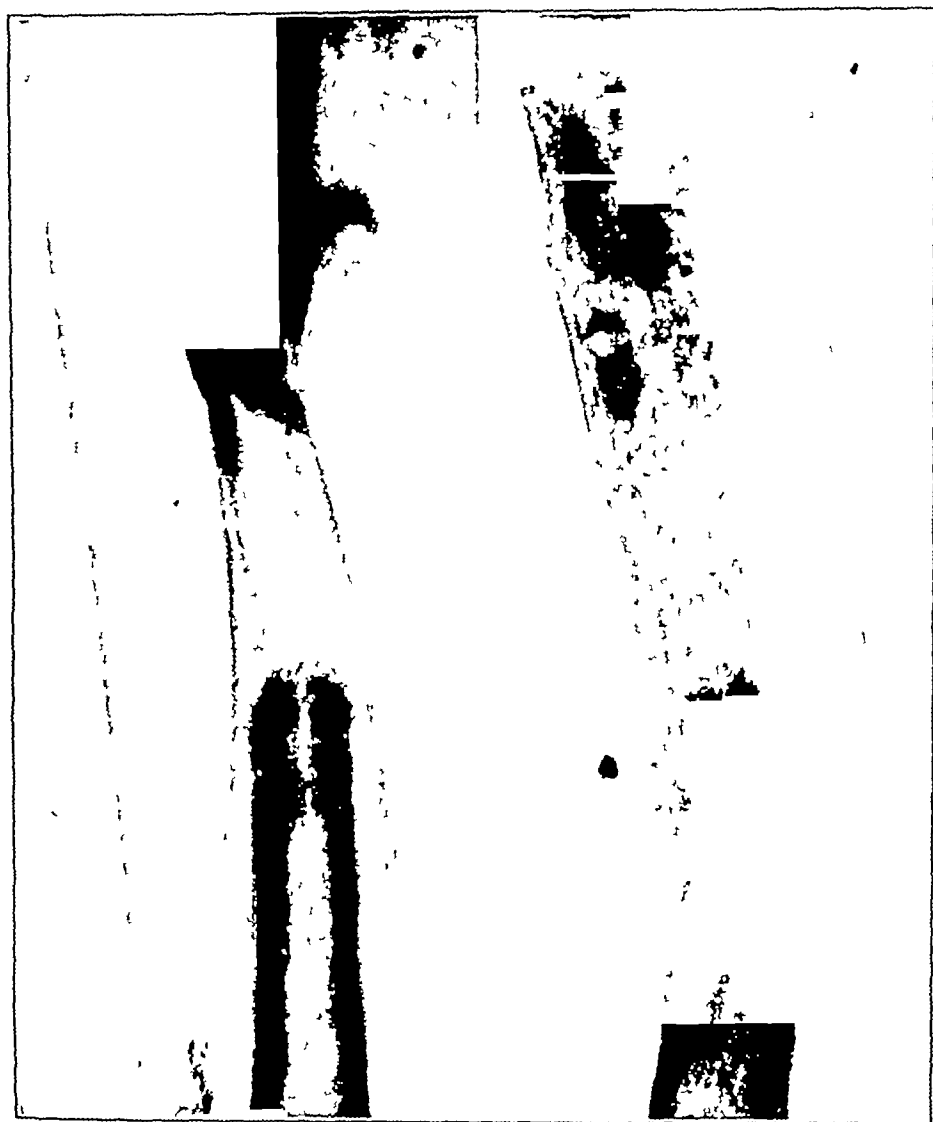


Fig 10 (Case 10)—Two months after operation Atrophy of graft

Dec 15 Firm union

Dec 21 Roentgenogram (Fig 8 B)

Dec 30 Small piece of graft ($\frac{1}{10}$ inch wide and 1 inch long) is loose This is removed More of edge of graft removed with chisel Incision packed and left open

Feb 14, 1920 Roentgenogram (Fig 9)

March 5 Firm union Small superficial ulcer size of lentil over graft

March 12 Reoperation Removal of bone Refractured at operation
 Partial success Patient in hospital

CASE 9—F L D, Pvt, Co K, 308th Inf, aged 29, Oct 4, 1918, high explosive wound of right shoulder and right jaw

Feb 1, 1919 Entered Letterman General Hospital Defect, right mandible, practically all of vertical ramus and half of horizontal ramus Large foreign body, upper lobe right lung Brachial palsy, right

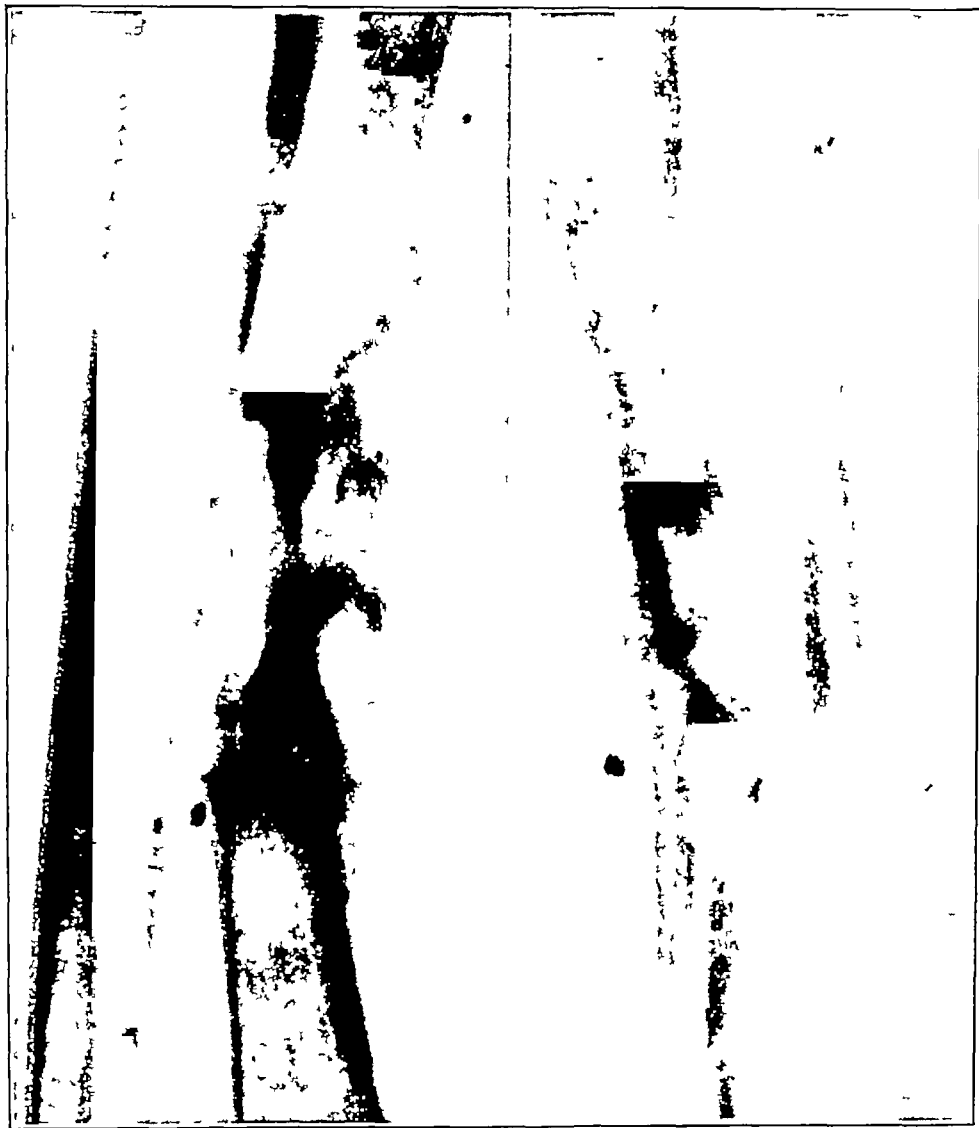


Fig 11 (Case 10)—Seven months after operation Firm union Graft has had several sequestrums removed from the gaps, shown by the light spots Increase in density since October, 1919 Compare with Figure 10

April 1 Rib graft. Posterior end of main fragment of jaw atrophic Mouth not entered Four inch piece, curved, of sixth rib removed Pleural cavity not opened Anterior end of rib split Posterior end of main fragment of jaw placed in trough and held with kangaroo suture Upper end of graft laid into region of condyle of jaw No fixation of upper end of graft

April 12 Wound healed

August 1 Can chew well

August 28 Discharged Deformity right maxilla, partial ankylosis jaw, unable to chew army rations Civil disability $\frac{1}{80}$

March 27, 1920 Fibrous band extending backward from site of fracture It is not possible to feel whether or not bone graft is present in this hard tissue Jaw gives man no trouble, can crack hard candy with it and can lift chair with his teeth

Complete success

CASE 10—F A, Pvt, Co M, 308th Inf, aged 29, Oct 14, 1918, high explosive wound of left forearm

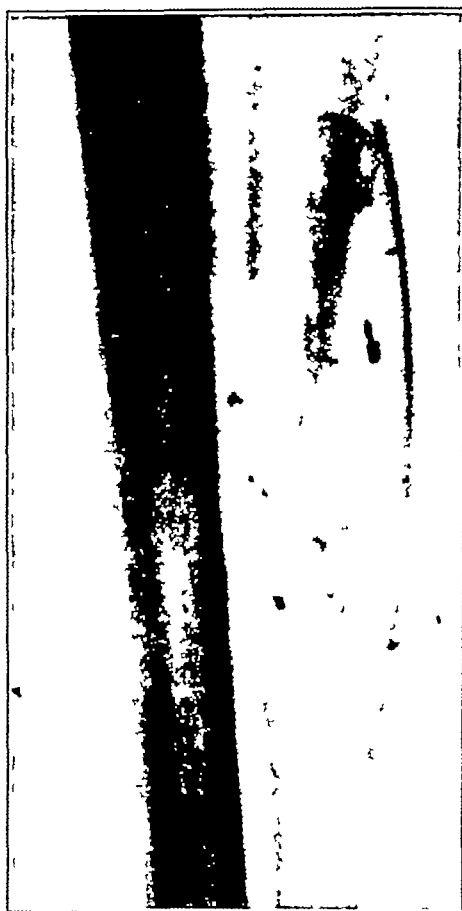


Fig 12 (Case 11)—Thirty days after operation Good alignment Union

July 3, 1919 Admitted to Letterman General Hospital Sinus leading down to left ulna Two-inch defect of left radius

July 12 Sequestrotomy Wound closed and healed by first intention

August 7 A rib graft inserted Four inches of rib removed, split, and tied around radius Pleura not opened

August 14 Cast removed Wound suppurating

Oct 7, 1919 Graft united at lower end, ununited at proximal end (Fig 10)

Jan 3, 1920 Operation Unabsorbed part of graft ununited It is removed and the incision left open

Feb 13 Roentgenogram (Fig 11)

March 15 Graft firmly united Good function of arm Wounds healed
Complete success

CASE 11—G H, Pfc, Co C, 28th Inf, aged 28, July 19, 1918, gunshot wound of left forearm

Sept 1, 1918 Healed, but reopened afterward for recurring suppuration

Feb 20, 1919 Admitted to Letterman General Hospital, where compound comminuted fracture of the middle third left radius with a small defect was found Partial interruption of median and ulnar nerve also noted

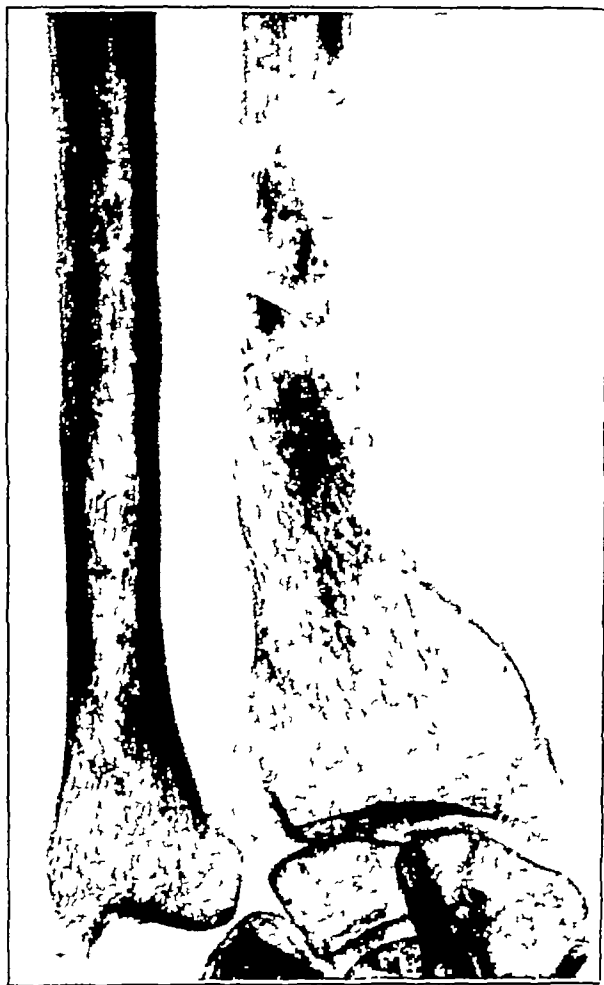


Fig 13 (Case 13)—Before rib grafting operation, after implantation of bone chips

A sequestrotomy was first performed, then between Aug 2 and 15, 1919, a rib graft was inserted by Captain Haas

September 15 Roentgenogram (Fig 12)

Nov 18 Discharged Partial paralysis of median and ulnar nerves Partial ankylosis of left wrist and of all carpal and phalangeal joints Weakness of left hand Civil disability $\frac{1}{3}$ Bone graft firmly united Records lost
Complete success for bone graft

CASE 12—H E S, First Lieut, Co F, 58th Inf, aged 28, Oct 5, 1918, high explosive wound of right forearm Bone graft from tibia inserted by Major Albee

March 24, 1919 Primary union Radius refractured

June 23 Letterman General Hospital Ununited fracture of radius and ulna, lower third

July 8 Operation performed by Captain Haas Tibial graft united at lower end Nonunion, upper end Graft in upper fragment being absorbed Easily pulled out of bed, but surrounded by new bone Piece of rib excised, wedge cut in upper fragment, end of rib anchored into same Lower end split, lower fragment inserted into trough

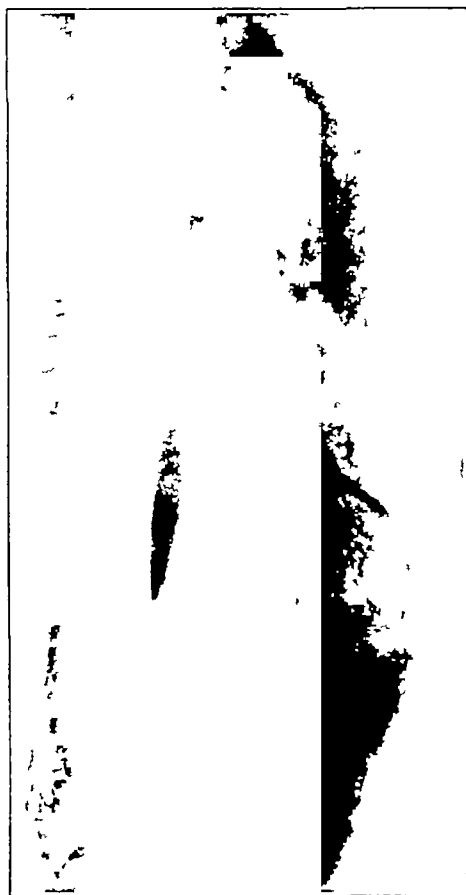


Fig 14 (Case 13)—Refracture of graft at original site of nonunion Part of graft distal to refracture was absorbed by March 13, 1920 Compare with Figure 15

July 23 Serous discharge

September 23 Sinuses Sequestrums removed Both ends of graft ununited

October 18 Third operation Remains of graft united to surrounding tissue Ridge of new bone under graft continuous with lower fragment, in contact with upper fragment, but not united

Still in hospital Nonunion Failure because of suppuration

CASE 13—J O M, Pvt, Co K, 308th Inf, aged 29, Sept 29, 1918, high explosive wound of left forearm

September 30 Bone fragments removed

Dec. 18, 1918 Admitted to Letterman General Hospital Nonunion of radius

Jan 20, 1919 Operation Small spike chiseled out from proximal fragment and jammed into defect Remaining space filled with bone chips

Nonunion



Fig 15 (Case 13)—Firm union, upper end of graft Refracture through lower end at site of original nonunion Absorption of graft distal to site of refracture Compare with Figure 14 Bracket indicates part of graft that has been absorbed

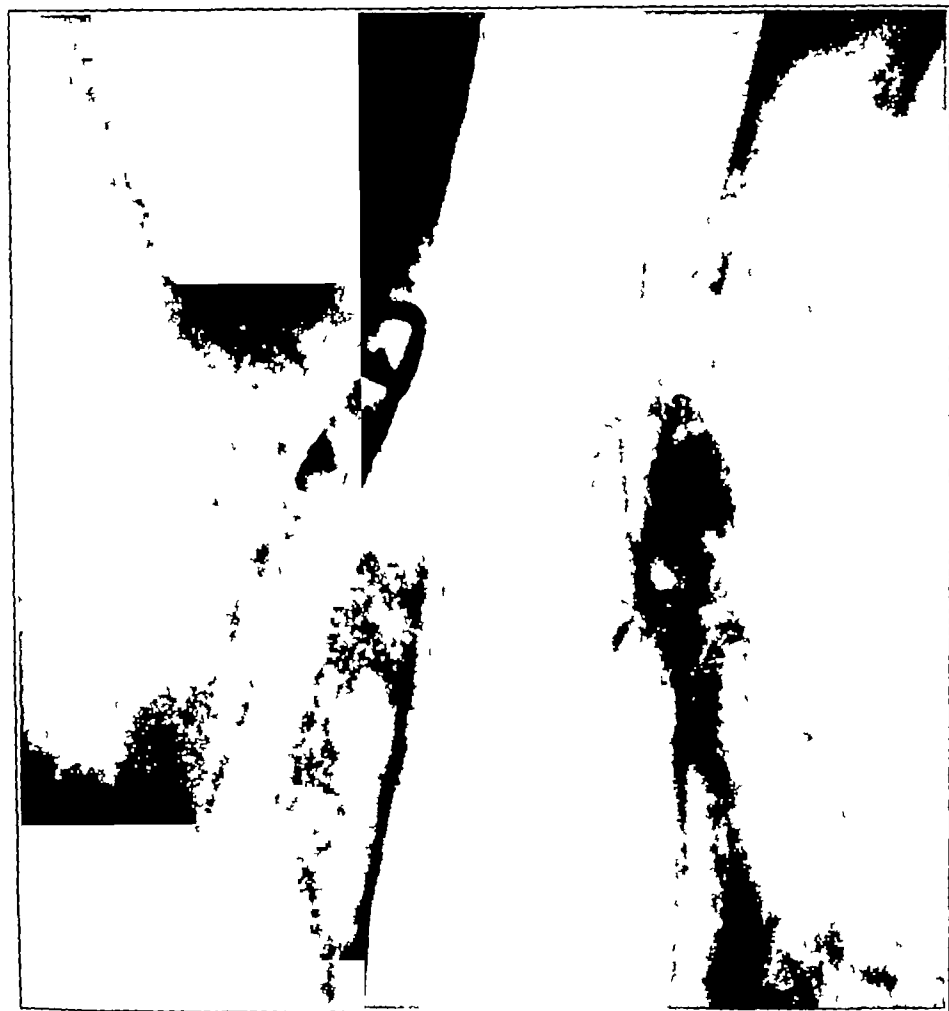
July 31 Second operation Rib graft Fibrous separation $\frac{1}{8}$ inch, $\frac{3}{4}$ inch of bone removed. Piece of rib $2\frac{1}{2}$ inches removed, split, and fragments tied into trough Pleura not opened

Jan 9, 1920 Discharged Defect of radius, junction middle and lower third Destruction of flexor and extensor muscles Ankylosis (partial) wrist Civil disability $\frac{1}{2}$

March 13 Graft firm at both ends Fracture in middle Good grip
Partial success Fracture of graft

CASE 14—J A, Pvt, Co I, 111th Inf, aged 31, Oct 2, 1918, machine gun bullet wound of left arm

October 3 Bone removed at evacuation hospital Musculospiral palsy



A

B

Fig 16 (Case 14)—A, before grafting operation B, eight weeks after operation Sepsis Absorption and disintegration of graft

Jan 17, 1919 Letterman General Hospital Nonunion of humerus Enormous defect of middle third Partial musculospiral palsy

March 18 Neurolysis radial nerve Bone suture with silver wire

June 12 Nonunion

August 19 Rib graft Four pieces of rib fastened about fragments
Pleura not opened Infection and copious drainage



Fig 17 (Case 15) —Before operation



A

B

Fig 18 (Case 15) —*A*, eleven weeks after operation Union Good alignment *B*, fracture and absorption of graft through middle, arrow points to new callus about site of fracture of graft Firm union, both ends Six months after operation

August 21 Sequestrotomy

October 15 Roentgenogram (Fig 16 B)

Dec 10, 1919 Nonunion

March 5, 1920 Flail arm Remains of graft in good position and united to upper and lower fragments by callus Fragments run out into sharp spikes
Good grip Radial palsy cured

Failure

CASE 15—L H B, Pvt, Co E, 309th Inf, aged 25, Nov 1, 1919, machine gun bullet, left elbow Debridement and wound healed, February, 1919



Fig 19 (Case 16)—Twenty-eight days after Albee operation Lower end of tibial graft slipped from slot into which it was implanted

July 3, 1919 Letterman General Hospital Flail elbow, left Wrist drop, left Large defect

July 19 Rib graft One and one-half inch defect of ulna bridged over by 4½ inches of sixth rib Head of radius inaccessible Small sliver of rib laid against it, but does not bridge gap accurately Pleura opened

Sept 12 Beginning union Wounds healed

October 7 Roentgenogram (Fig 18 A)

Oct 10 Firm union

Jan 20, 1920 Roentgenogram (Fig 18 B)

RESULTS IN TWENTY-TWO CASES OF RIB GRAFT

Case No	Name	Kind of Injury, Region, Date*	Size of Defect	Operation			Time Between Injury and Graft	Time Between Wound Healed and Graft	Suppuration	Time Between Graft and Union	Time in Onset	Refracture	Result	Remarks	Surgeon's Certificate of Disability
				First	Second	Third									
1	A O	H E, wrist 5/4/18	All carpal ex-cept trapezium	Rib graft, 2/3/19	Graft removed, 2/28/19		8 mos		Yes				Failure, acute suppuration	Subcutaneous emphysema	Leather wristlet, flail wrist, O 1/2 5/2/19
2	A A	G S W, middle and lower 3d radius, 6/16/19	Small	Rib graft, 8/18/19			2 mos		No	3 mos	3 mos	No	Success		To full duty 12/22/19
3	B T P	G S W, middle ulna, 9/29/18	2 in	Rib graft, 7/10/19	Sequestro- tomy 11/7/19	Sequestro- tomy 1/30/20	9 1/2 mos		Yes	3 mos	3 mos	At reoperation Mar '20	Partial success	Reoperated later with removal of bone	Still in hospital 3/23/20, operated and refractured (indication for operation ?)
4	B P	H E, ulna and radius, upper third 6/29/18		Freshened and wired 1/21/19	Mortise, 5/6/19	Rib graft, 8/5/19	13 1/2 mos	About 11 mos	No	2 mos	2 mos	No	Success	Two previous osteotomies for malposition second one infected	O 1/12, 1/16/20
5	O O	M G B, lower third humerus, 9/29/18	2 in	Bone suture, 5/24/19	Rib graft, 8/12/19		10 1/2 mos					Yes	Failure	Musculospiral palsy	S O D, 1/19/20 (1) palsy musculospiral, O 1/4, (2) nonunion humerus, O 1/4
6	D I	H E, middle and lower third radius, 9/29/18	3 1/2 in	Albee, 2/6/19	Rib graft, 5/13/19		(1) 4 1/2 mos (2) 7 mos		No	3 mos	3 mos	No	Success		O 1/4, 9/18/19 anky- wrist, tendon con- tracture
7	P J S	H E, mid- dle and lower third radius 9/4/18	1 in	Chip graft 2/6/19	Rib graft, 5/17/19		8 1/2 mos	(1) 1 mo (2) 4 1/2 mos	No	3 mos	3 mos	No	Success		O 1/4, 9/14/19, synos- tosis (partial) radius and ulna, fibrous an- kylosis (partial) sec- ond metacarpopha- langeal joint
8	E R O	H E mid- dle and lower third radius 10/12/18	1 1/2 in	Rib graft 7/23/19	Sequestro- tomy 12/30/19	Bone removed 3/12/20	9 1/2 mos		Yes	4 1/2 mos		Yes (at reoperation)	Partial success	Reoperation after firm union (reason ?) re- fractured at operation	Ulnar and median palsy, still in hos- pital
9	F L D	H F, jaw 10/14/18	1/2 of jaw	Rib graft, 4/1/19			7 mos	3 mos	Yes				Success	Large foreign body of chest brachial palsy (partial)	S O D, O 1/20, 8/28/19, 5 mos post oper
10	F A	H E, mid- dle third radius 10/14/18	1 in	Sequestro- tomy, 7/12/19	Rib graft 8/7/19	Sequestro- tomy, 1/3/20	11 mos	1 mo	Yes	(1) 3 mos (2) 7 mos		No	Success	Suture after seques- troctomy	Still in hospi- tal, wounds healed

11	O H	G S W, middle third radius 7/10/18	1/2 in	Rib graft between 5/2-15/10	Rib graft, 9/23/10, graft alive	Incision 10/18/10, graft alive	12 1/2 mos	No	3 mos	2 wks ?	No	Success	Ulnar and median palsy (partial)	S O D palsy (partial) rad and ulnar nerves anky (partial) all carpal and phalangeal joints C 1/2 11/15/19 Still in hospital
12	H L S	H F lower third radius and ulna, 10/5/18		Rib graft Capt Evans 7/8/10	Incision 9/23/10, graft alive	Incision 10/18/10, graft alive	9 mos	Yes	Nonunion upper end		Yes	Failure	Bone graft (Major Albee), 3/24/15, rib jammed into wedge, upper end	
13	J O M	H F lower third radius 10/29/18	1/28/10	Chip graft	Rib graft 8/31/10		10 mos	Late				Partial success	Destruction muscles	S O D, 1/9/20, defect left rad, destruction rad refer and exten muscles, O 1/2 Still in hospital
14	I A	M G B, lower and middle third humerus 10/2/18	2/3 in	Wired 3/18/10	Rib graft, 8/19/10	Sequestro- only 10/21/19	10 1/2 mos	Yes	Nonunion			Failure	Radial palsy (partial)	
15	L H B	F G B radius and ulna upper third, 11/11/18	1 in	Rib graft 8/19/10			8 1/2 mos	No	2 mos		Yes	Success	Radial palsy	Still in hospital (wrist drop)
16	M K	M G B middle third radius 9/29/18	1 3/4 in	Albee 3/6/10	Rib graft 5/15/19		7 1/2 mos	No	2 3/4 mos		No	Success	Partial inteross and median palsy Albee too small, slipped in cast	S O D, O 1/2 partial med an palsy, 9/26/19
17	O W I	H F, lower third radius 9/29/18	2 in	Sequestro tomy ster ile pus 8/24/10	Rib graft, 8/28/19		11 mos	No	6 wks		No	Success	Ulnar palsy and suture, 5/15/19	Still in hospital
18	R T	H F mid ole of tibia, 11/1/18	2 in	Rib graft, 8/31/10			9 mos	Yes	2 1/2 mos, upper and lower end		No	Success	Temperature reaction, no sequestrums	Still in hospital drop foot, loss ext ten dons
19	R L	H F mid ole third radius 8/29/18	2 in	Rib graft 10/18/10			14 1/2 mos	Late			Yes	Partial success	Pus on 7th day s nus closed 6 wks later, no sequestrums	Still in hosp, refracture post inteross palsy, S O D, 8/13/20, O 1/2, ankylosis (par tial) wrist
20	S T	C S W upper third humerus, 10/28/10	2 1/2 in	Rib graft 8/12/10			9 1/2 mos	Late			Yes	Partial success	Pus 1 mo after oper, hemolyt strept.	Still in hospital, frac ture, fibrous union, sinus closed, Jan '20, following erysipelas
21	S W	O O F ulna and radius lower third, 3/15/18	Slight	Chip graft, 6/12/19	Rib graft 8/15/10		17 mos	No	1 mo beginning, 2 mos firm		No	Success	Two previous operations in other hospitals	S O D, O 1/2, anky losis (partial) wrist, 11/14/19
22	S F	O O F ulna and radius, upper third, 10/1/18	Slight	Rib graft, 4/19/10			6 1/2 mos	No	3 mos		No	Success	Nonunion lower end of graft, but good function	Discharged 8/14/19

* In this column, H F represents high explosive, G S W, gunshot wound, M G B, machine gun bullet and O O F, compound comminuted fracture
† 1/2 represents civil disability, one half

Jan 28 Graft fractured at middle
 Feb 17 Broken graft uniting
 Feb 25 Firm union of ulna Nonunion of radius Good power in elbow
 Wrist drop Still in hospital for wrist drop
 Success

CASE 16—M K, Pvt, Co H, 147th Inf, aged 31, Sept 29, 1918, machine gun bullet, left forearm Partial paralysis of posterior interosseus

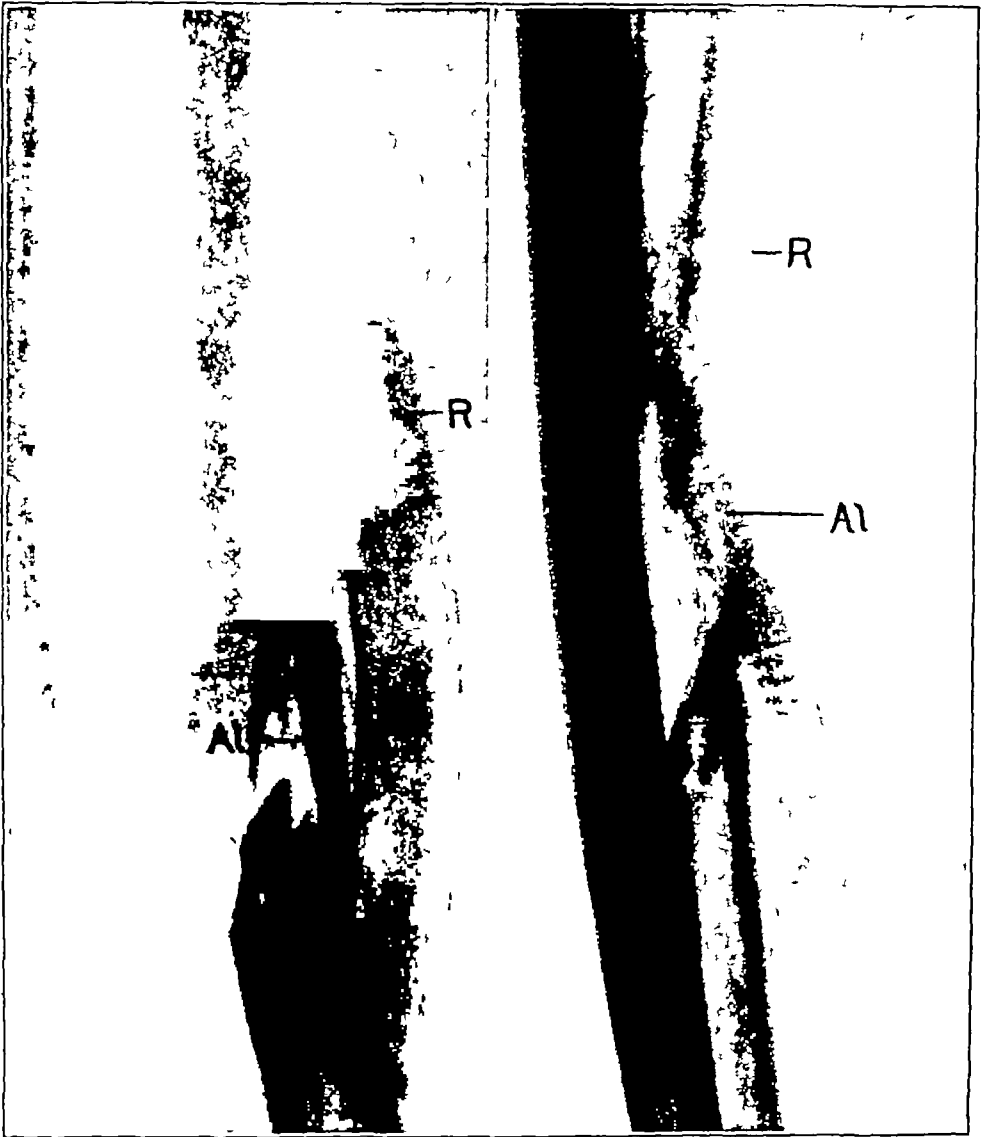


Fig 20 (Case 16)—Firm union of rib graft Previous Albee graft lies under rib graft Three months after rib graft operation R, rib graft, Al, Albee graft

Jan 7, 1919 Admitted to Letterman General Hospital Three cm defect middle third left radius

March 6 Albee graft removed from tibia, edges sharpened into wedge, forced into crack in each fragment No suture

April 3 Roentgenogram (Fig 19)

April 26 Upper end of graft became loose Soon after operation displaced from crack

May 15 Rib graft Previous graft ununited at both ends Distal end firmly embedded in slot made at operation March 6 Four inches of sixth rib removed, split and tied about bone Original tibial graft left in place Minute opening in pleura

August 8 Firm union Discharged Partial paralysis of median nerve Civil disability $\frac{1}{8}$

August 15 Roentgenogram (Fig 20)

Complete success



Fig 21 (Case 17)—*A*, before operation Radial deviation of wrist *B*, forty days after operation Correction of radial deviation *C*, five and one-half months after operation Firm union, ends of graft *F*, fracture through middle of one graft

CASE 17—O W J, Sgt, Co L, 363d Inf., aged 25, Sept 29, 1918, two inches of radius carried away by shell Fragments removed same day

April 12, 1919 Letterman General Hospital Two-inch defect lower end right radius Partial ulnar palsy, right

May 15 Resection and suture of ulnar nerve
 July 24 Sequestrotomy of radius
 August 28 Rib graft Five inches of seventh rib split and fastened around radius Pleura not opened
 Sept 18 Primary union
 Oct 7 Union firm (Fig 21 B)
 Feb 4, 1920 Roentgenogram (Fig 21 C)
 March 5 Firm union Some projection ulnar styloid and volar displacement of carpals Dorsal extension of wrist impossible beyond straight line
 Partial ulnar palsy
 Complete success

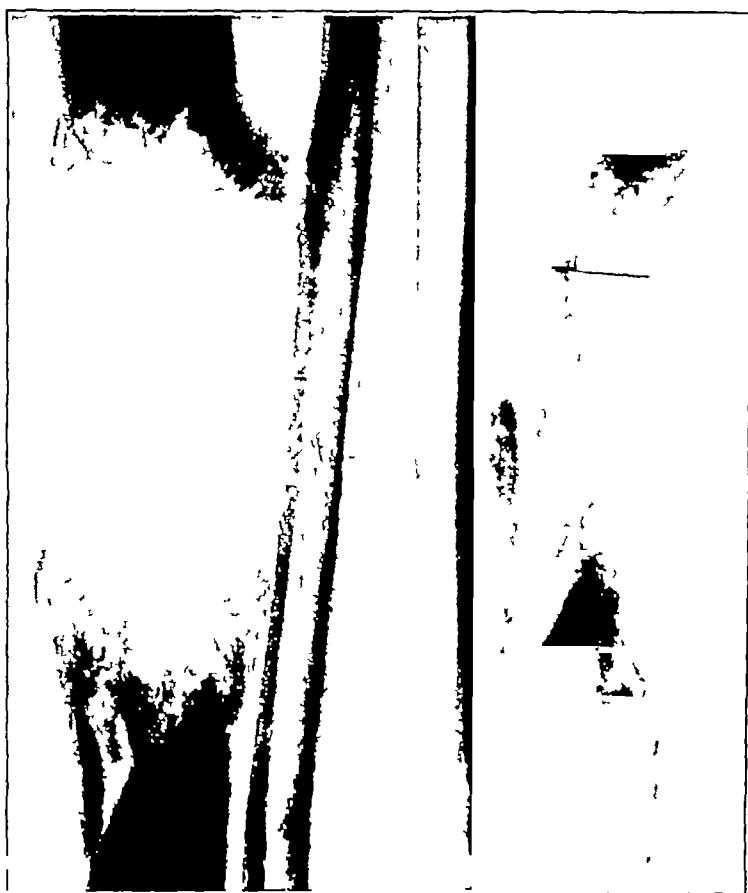


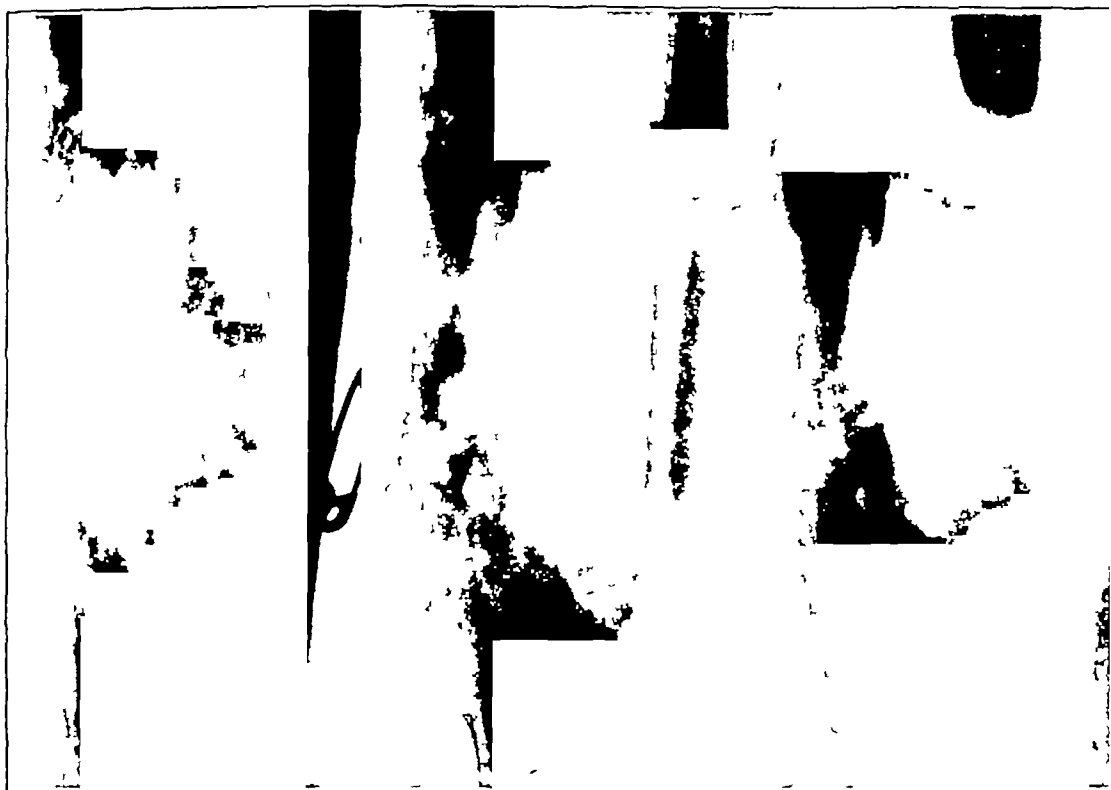
Fig 22 (Case 18)—Tibial defect before operation Synostosis of upper tibial fragment to fibula

CASE 18—R T, Pfc., Co E, 361st Inf, aged 24, Nov 1, 1918, high explosive wound of right tibia

July 4, 1919 Letterman General Hospital Wound over middle right tibia Small granulating area Defect 2 inches long in middle of right tibia

July 31 Rib graft Incision on inside of leg behind old scar Back of tibia exposed Part of scar separating ends of bone excised Five inches of rib removed, split, and laid against back of tibia Kangaroo tendon encircling rib passed through drill hole in tibia Long posterior splint Pleura not opened

August 8 Wound suppurating



A

B

C

Fig 23 (Case 18)—*A*, nine weeks after rib graft *B*, five and one-half months after rib graft Fracture of graft through its middle, in spite of much increase in density *C*, six and one-half months after operation Beginning union of refracture of graft *R*, refracture, *R U*, refracture united

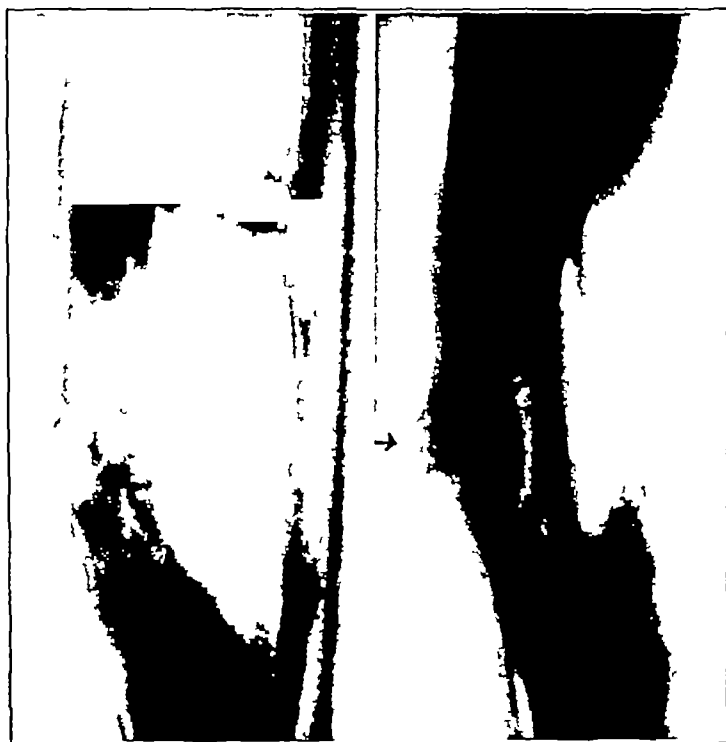


Fig 24 (Case 18)—Nine months after operation Union of refracture of graft with considerable callus Arrow points to callus at site of fracture of graft

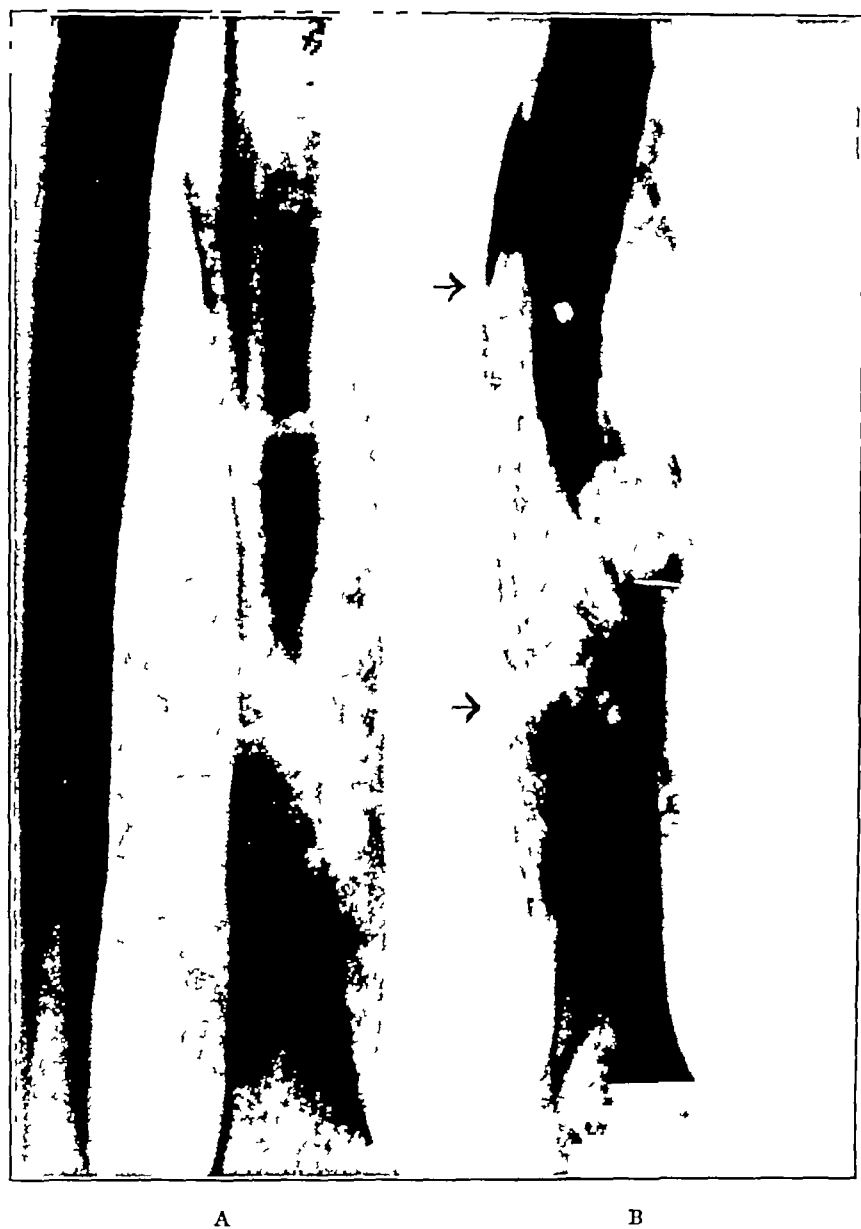


Fig 25 (Case 19) —*A*, thirty-seven days after operation. *B*, three and one-half months after operation. Arrows point to absorption of graft at site where kangaroo tendon was tied. Refracture occurred later at these places. Pressure atrophy (?) Suppuration about kangaroo tendon (?)

August 9 Chill

August 12 Temperature normal Wound gradually closed without sequestration

October 6 Roentgenogram (Fig 23 A)

Oct 8 Firm union upper end of graft Lower end movable Wound closed Double bar brace, gradual weight-bearing

Jan 13, 1920 Fracture of graft (Fig 23 B)

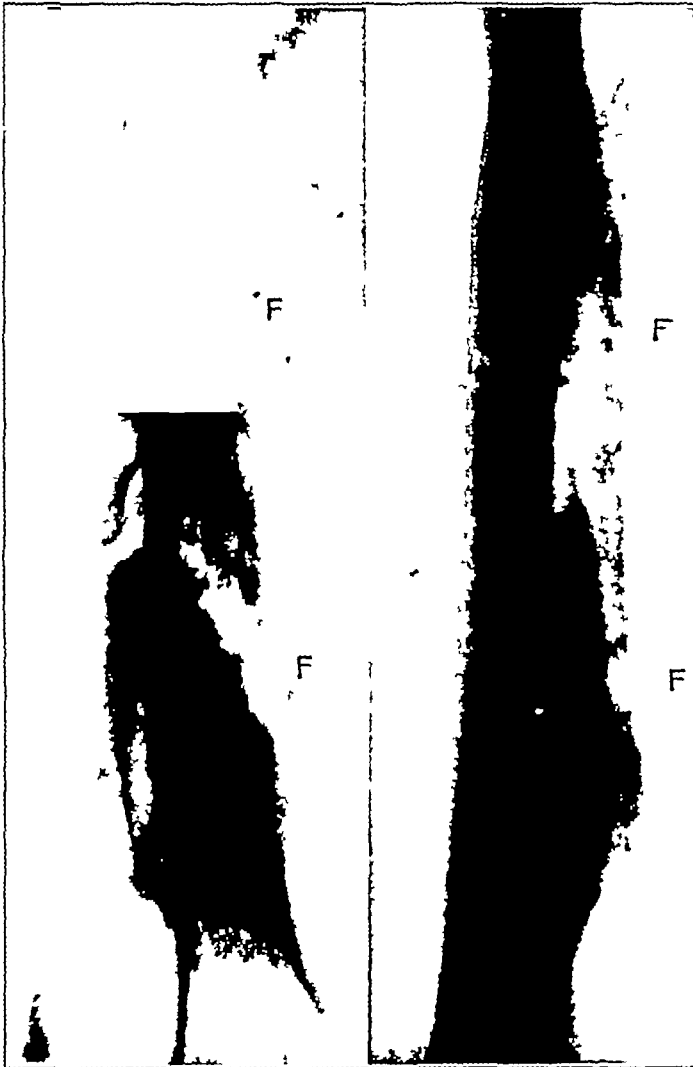


Fig 26 (Case 19) —Firm union, both ends of graft *F*, fractures at the middle

February 17 Beginning reunion

March 5, 1920 Walks with brace, but without stick or crutch Ridge of bone both on inside and outside of tibia Synostosis with fibula as a bridge of bone separate from graft Sinus closed Drop foot from loss of muscle

Complete success Patient can stand on grafted leg alone

CASE 19—R L, Pvt, Co L, 109th Inf, aged 27, July 30, 1918, high explosive wound of left forearm

Aug 10, 1919 Letterman General Hospital Wounds healed Compound comminuted fracture of radius Partial median paralysis

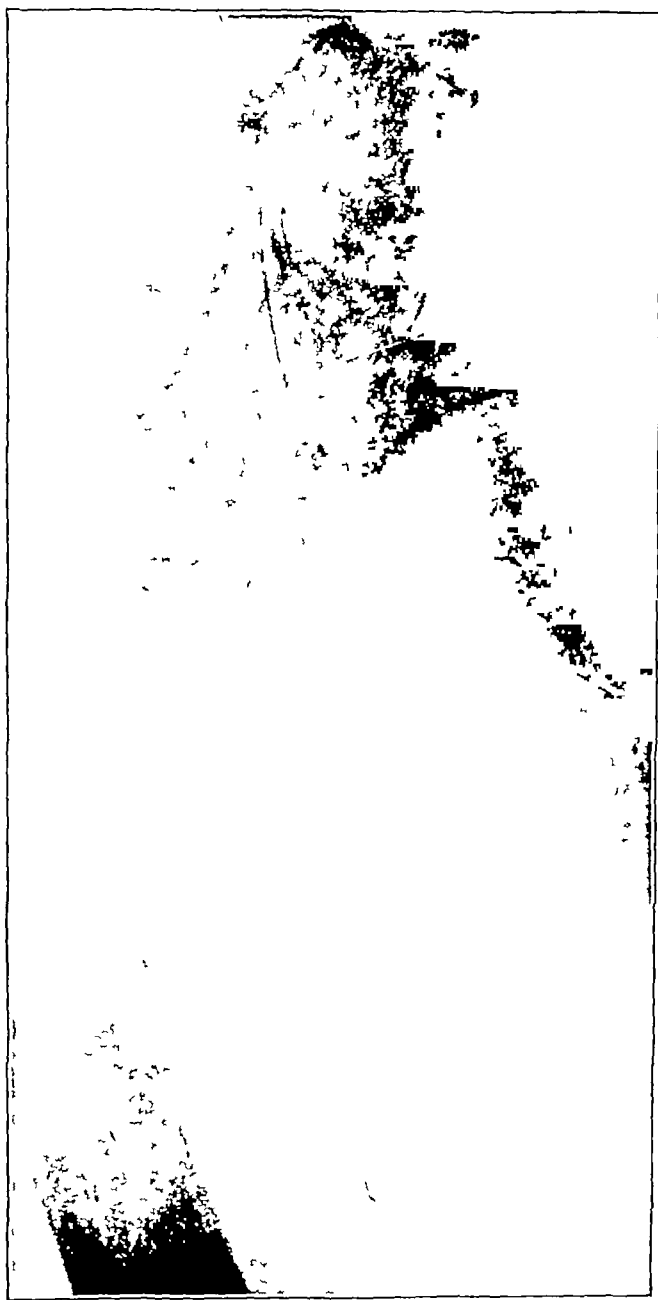


Fig 27 (Case 20) —Large defect, upper third of humerus Before operation

October 18 Rib graft Small defect Large soft callus Four inches of rib split and tied around defect Tendon transplantation at same operation Pleura not opened

October 31 Primary union

November 4 Pus



A

B

Fig 28 (Case 20) —*A*, union, upper and lower portions of graft. Beginning absorption of middle. Four months after operation. *B*, union of upper and lower portions of graft. Refracture through middle. Six months after operation.

November 29 Roentgenogram (Fig 25)

Dec 20 Closed

Refracture of graft some time after February 20, 1920 Fracture of graft in middle Both ends firmly welded to radius (Fig 26)

March 13, 1920 Discharged Partial ankylosis of wrist Civil disability $\frac{1}{8}$

March 29 Nonunion, but strong arm

Partial success

CASE 20 —S T, Pvt, Co D, 58th Inf, aged 25, Sept 28, 1918, gunshot wound of upper and middle third of left humerus Bone removed next day

July 4, 1919 Letterman General Hospital Two inch defect below head of humerus Accompanied by much soft tissue destruction No nerve lesion



Fig 29 (Case 21) —*A*, before operation Nonunion *B*, rib graft, twenty-nine days after operation

July 12 Rib graft Ends of humerus freed of periosteum Four inches of fifth and sixth ribs, left, removed Ribs split in half, each half fastened to ends of humerus by two kangaroo tendon sutures Space between grafts (new marrow cavity) filled with blood clot and iodoform powder Pleura not opened

August 15 Slight discharge

November 4 Roentgenogram (Fig 28 *A*)

Jan 9, 1920 Small sequestrums removed

January 12 Roentgenogram (Fig 28 *B*)

March 5 Sinus healed after an attack of erysipelas in January Head rotates with shaft, but lateral mobility present Nonunion Spike extends upward from lower fragment Refracture or absorption of graft Failure.

CASE 21—S W A, Pvt, 64th Balloon Company, March 15, 1918, fracture of radius and ulna, lower third, following balloon accident Two operations for nonunion

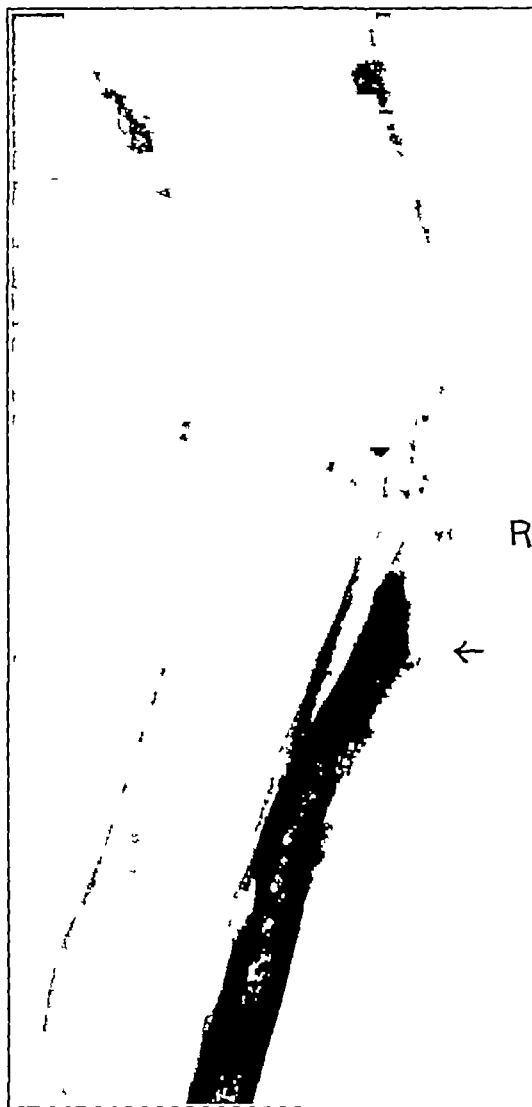


Fig 30 (Case 33)—Rib graft four months after operation R, rib graft Arrow points to beginning union

Feb 13, 1919 Letterman General Hospital Ununited fracture of radius and ulna lower third Small defect Open scar Silver wire in sinus

June 12 First operation Fracture exposed Small sequestrums removed Bone chips laid between fragments Nonunion

August 5 Rib graft Three inches of rib split and tied about radius Pleura opened, small hole

September 3 Roentgenogram (Fig 29 B)

September 5 Beginning union

October 7 Union firm Primary union of skin

November 4 Discharged Ankylosis (partial) right wrist Pain and weakness Civil disability $\frac{1}{10}$

Complete success

CASE 22—S E, Ensign, U S N R F, aged 22, Oct, 4, 1918, compound comminuted fracture of ulna and radius, right, upper third, aeroplane propeller

October 29 Fragment removed

December 26 Letterman General Hospital Partial ankylosis of elbow Wide separation of ulnar fragments

April 19, 1919 Rib graft One inch defect Two inches of sixth rib, left, removed Slot $\frac{1}{2}$ inch long in upper fragment for reception of graft Graft jammed into slot with hammer Lower end of rib split and tied around distal fragment Primary union

March 31, 1920 Firm union Extension to 170 degrees, flexion to 45 degrees, 20 degrees rotation Success Can play golf, normal use of arm

135 Stockton Street

THE ESTABLISHMENT OF SURGICAL PRINCIPLES IN THE TREATMENT OF FRACTURE OF THE NECK OF THE FEMUR

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In reviewing the general literature on the subject of fractures and their treatment, one is impressed with the fact that one injury, and only one, is regarded as a hopeless proposition—fracture of the neck of the femur. The more modern authors mention various forms of treatment and concede the possibility of the union of such a fracture, but the general tone adopted is one of discouragement and disillusionment. In one of our best known textbooks,¹ the section on treatment of this injury begins “The first indication is to save life.” In the section on fractures of the skull and of the pelvis, notably grave conditions, the author says nothing about life saving as a primary indication for treatment. Indeed, one would suppose that life saving was the essential preliminary to any treatment, and that it might be taken for granted. Why, then, is its necessity emphasized in connection with this one injury?

In answering this question, one must review the history of the injury. I take as my premise that fracture of the neck of the femur is now very generally regarded as (1) an injury of advanced age, (2) an injury for which there is no standard treatment, and, (3) an injury differing from others in that the impression is widely prevalent that an intracapsular fracture of the neck of the femur is per se incapable of repair.

It is extraordinary that one bone in the skeleton should be distinguished for its lack of a characteristic accorded to all others. As an explanation of this invidious distinction, I can do no better than to quote at length from the author whose opinion, wrongly, I believe, has always been adduced in support of the proposition that intracapsular fracture of the neck of the femur could not unite.² Sir Astley Cooper² said

1 Stimson, L J. Fractures and Dislocations, Ed 6, Philadelphia, Lea & Febiger, 1910, p 354

2 Cooper, Astley. Dislocations and Fractures, Ed 1, London, John Churchill, 1822

Much difference of opinion has existed on the subject of the union of the fractured neck of the thigh bone. It has been asserted that these fractures unite like those of other parts of the body, but the dissections which I made in early life and the opportunities I have since had of confirming these observations, have convinced me that fracture of the neck of the thigh bone, of the patella, olecranon, condyle of the os humeri, and of the coronoid process of the ulna generally unite by ligament and not by bone. This principle I taught in my lectures for thirty years and it is a most essential point, as it affects the reputation of the surgeon, as well as being a subject of some interest in forensic medicine, for if these fractures unite like those of other parts of the body, the patient who remains lame after the treatment would undoubtedly have a right to such redress from the surgeon at the hands of the law.

Nothing is known in our profession by guess, it is right, therefore, that those who are studying their profession should be aware that there is no short road to knowledge—that observation upon the diseased living, examinations of the dead, and experiments upon living animals are the only sources of true surgical knowledge and that indications from these are the sole bases of legitimate theory.

In the examinations which I have made of transverse fractures of the cervix femoris entirely within the capsular ligament, I have only met with one in which a bony union had taken place or which did not admit of a motion or one bone upon the other. To deny the possibility of this union, and to maintain that no exception to the general rule can take place, would be presumptuous.

Much trouble has been taken to impress the minds of the public with the false idea that I have denied the possibility of union of the fracture of the neck of the thigh bone and I therefore beg at once to be understood to contend for the principle only, that I believe the reason that fractures of the neck of the thigh bone do not unite is, *that the ligamentous sheath and periosteum of the thigh bone are torn through*, that the bones are consequently drawn asunder by the muscles, and that there is a want of nourishment of the head of the bone, but I can readily believe that if a fracture should happen without the reflected ligament being torn, that as the nutrition would continue, the bones might unite but the characters of the accident would differ, the nature of the injury could scarcely be discerned, and the patient's bone would unite with little attention on the part of the surgeon.

Cause of the want of union, first, is the want of proper apposition of the bones, for if in any part of the body the extremities of a broken bone be kept asunder ossific union will under ordinary circumstances be prevented.

The neck of the thigh bone, when broken, is placed under similar circumstances (to the fractured patella) for, by contraction of the muscles it is no longer in apposition with the head of the bone and is therefore prevented from uniting, if this, however, were the only obstacle, it might be argued that the retraction of the thigh bone could be prevented by bandaging and extension, the truth of which cannot be denied, but it is scarcely possible, even for a few hours, to preserve the limb in exact apposition, as the patient, on the slightest change of posture, produces instant retraction by bringing into action those powerful muscles, which pass from the pelvis to the thigh bone.

A second circumstance which prevents the bony union of these fractures is want of pressure of one extremity of the broken neck upon the other, even though the limb preserves its length, and the fractured parts are consequently

not much displaced. This want of pressure may arise in some degree from the excessive secretion of serous synovia which follows the accident, but principally from the action of the muscles which separate the bony surfaces.

A third reason which may be assigned for the general want of union of this fracture is the almost entire absence of nutrition in the head of the thigh bone when separated from its cervix, its life being supported by the ligamentum teres, which has only a few minute vessels ramifying from it to the head of the bone.

The fourth reason is want of constitutional vigor which always accompanies old age.

It seems strange that a Fellow of the Royal Society, who could so clearly summarize the results of his observations, did not accomplish the final step in his reasoning—that all the obstacles enumerated against repair were due simply to lack of command of an effective treatment. But in Sir Astley's day the neck of the femur was not the only bone "*generally uniting by ligament*." It shared the burden with the "patella, the olecranon, the condyles of the os humeri, and the coronoid process of the ulna." One by one, as the science of treatment, particularly in the sphere of open operation, progressed, these other bones have been shown, when their fractured surfaces have been placed and held in apposition, to be capable of bony union.

In 1904, it was demonstrated that under favorable circumstances the neck of the femur might also so unite. In other words, a proper form of treatment was for the first time described.³ Originally devised for the treatment of fractures in children, or in young and vigorous adults, its application has been gradually expanded until now it has been successfully applied to all classes of cases.

That this treatment has not been widely adopted is a source of surprise and regret to those familiar with it. The present status of treatment of fractures of the neck of the femur is evidenced by the subjoined quotation.⁴

After carefully reviewing the case records of these patients, the outstanding points established were that the nonunion in the majority resulted from an incorrect diagnosis at the time of accident, and that in the minority, even when the proper diagnosis had been made, no treatment had been carried out, often, it is true, for some justifiable reason. In a certain few, the measures used had been rather in the form of a surgical ritual and were not in any sense of the word adequate. It was astonishing to ascertain how often elderly persons, who after a severe fall were disabled on account of intense pain in the hip, were told without being carefully examined that they were suffering from a sprain, the fracture not being diagnosed until months later, usually by

3 Whitman, Royal. A New Treatment for Fracture of the Neck of the Femur, Med Rec 65 441, 1904.

4 Henderson, M. S. Ununited Fractures of the Hip, Surg., Gynec & Obst 30 145 (Feb.) 1920.

another consultant. Another somewhat common story was that the physician who was called in carefully measured the legs and finding no shortening or eliciting no crepitus, diagnosed a sprain without resorting to radiography. Weeks or months later a consultation necessitated by continued disability revealed shortening of the affected leg, crepitus on manipulation, and a roentgenograph established the diagnosis of fracture. The probable explanation of this is that what was originally a more or less weakly impacted fracture broke down through inadequate fixation of the limb. *In none of the cases in this series was there a history of really proper treatment for the fracture. Good treatment had been instituted in a few instances, but for some reason it was not prolonged enough.* The patient may have been unruly, the supervision too weak, or complications, such as impending pneumonia, may have necessitated a discontinuance of treatment.

CAUSES FOR FAILURE TO APPLY THE ABDUCTION METHOD

Such a state of affairs should not be allowed to persist, and this article is an inquiry into the causes for failure to adopt the only proper method of treatment for a crippling injury. I have quoted, and used as texts for comment, excerpts from several authors. This is not done in a spirit of criticism. The quotations are offered as fairly reflecting the general attitude toward the treatment of the injury, which is notable chiefly for its lack of any general standard, either in methods to be applied or results to be expected. To illustrate this haziness, I have taken three passages from a recent monograph⁵. The author begins his article, a description of a splint he has devised, with a few home truths

1 Experience has taught that these patients (suffering from fracture of the neck of the femur) bear confinement in bed and the presence of cumbersome dressings very badly

2 Probably most surgeons treat these cases with sandbags and extensions. Imperfect rigidity of the parts is thus obtained

3 Plaster bandages enclosing more or less of the trunk and the thigh are used by many

If one were to read these statements and apply them to a patient suffering from a fracture of the shaft of the femur, what would be the impression of the quality of the treatment that that particular class of patients was receiving? Who would keep a patient suffering from a fracture of the shaft of the femur flat on his back, unable to move because of sandbags, making whatever movements he did at the cost of excruciating pain, because of the "imperfect rigidity of the parts thus obtained"? Who, if he used plaster, would use it "enclosing more or less of the trunk and thigh"? Would not the most charitable comment on such treatment be that the one who used it was a little uncertain in his mind as to the principles of the

⁵ Masland, H. C. A Form of Splint Available in the Treatment of Fractures of the Neck of the Femur, *Ann Surg* 71: 501 (April) 1920

treatment he was trying to apply? Certainly one would not be over-optimistic as to the result to be expected. On the basis of such treatment one would scarcely feel justified in making the statement that fractures of the shaft of the femur were a class of cases not adapted to the application of surgical principles, and that the surgeon in charge of such a case was to be congratulated if he succeeded in saving his patient's life. In short, one would say that the surgeon was blaming Nature for the natural consequences of his improper treatment.

Has not this been the attitude of surgeons in general for the past hundred years toward fracture of the neck of the femur?⁶ Because such fractures "occur most commonly in elderly persons," and because surgeons have not had at their command means for the application of such surgical principles as they would at least attempt to apply in the treatment of any other fracture, have they not been prone to excuse their universally bad results on the ground of "lowered vitality and structural weakening of the part"?⁷

I think it may now be conceded that authorities on the subject of fractures are agreed that the treatment of fractures of the neck of the femur by the abduction method is the only method that applies, or attempts to apply, surgical principles to that form of injury.⁷

Under anesthesia initial manual traction on the affected limb overcomes shortening. Full abduction and slight inward rotation places the fragments in apposition and restores the normal angle described by the neck of the femur with the shaft. Full abduction of the thigh on the pelvis holds the fragments in position by tension of the capsular ligaments and relaxation of the muscles whose contraction tends to produce overriding of the fragments. What is most important, it assures the mutual pressure of the fractured surfaces, which was insisted upon by Sir Astley Cooper as being essential to repair. In combination with full abduction, hyperextension of the thigh on the pelvis is an additional safeguard against the force of gravity in preventing dorsal displacement of the distal fragment (Figs 1, 2, 3 and 4). Any one who has performed an open operation on such a fracture has had the opportunity to verify these facts by his own observation.

6 Cotton, F J. *Ann Surg* **63** 366 (March) 1916.

7 Albee, F H. *Orthopedic and Reconstruction Surgery*, Philadelphia, W B Saunders Company, 1919, p 600. Tubby, A H. *Deformities, Including Diseases of the Bones and Joints*, London, the Macmillan Company **1** 595-601, 1912. Judet, H. *Traité des Fractures des Membres*, Paris, A Maloine, 1913, p 356. Scudder, C L. *The Treatment of Fractures*, Ed 8, Philadelphia, W B Saunders Company, 1915, p 422. *A System of Surgery*, New York, Funk & Wagnalls Company **3** 648, 1914. DaCosta, J C. *Modern Surgery*, Ed 8, Philadelphia, W B Saunders Company, p 673.

Indeed, to any one who has done so the proposition seems so simple and self-evident that he is inclined to wonder at the slow general progress that has been made toward its adoption

I take it that the majority of surgeons are conscientiously interested in the welfare of their patients, and that we may not ascribe the lethargy of the profession toward the adoption of a new principle either to stupidity or to laziness. One is therefore bound to inquire what the further causes of such a condition may be. Having pointed out a theoretical truth, we may not yet be satisfied if almost universal human fallacies prevent its application. To use a homely illustration, we have not done our duty during a smallpox epidemic if we content ourselves with recommending vaccination. We must see that the vaccination takes. What, then, are the causes militating against the application of the abduction treatment of fracture of the neck of the femur?

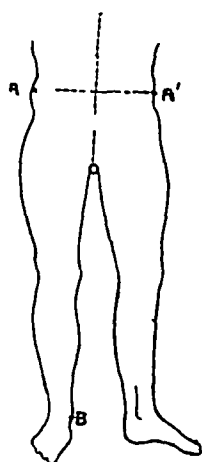


Figure 1

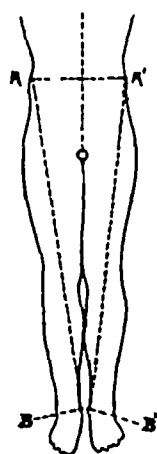


Figure 2

Fig 1—Attitude of the limb in fracture of the neck of the left femur

Fig 2—Limbs parallel traction on the affected limb has overcome shortening. Distance $A'B'$ must equal distance AB

The first is the general atmosphere of discouragement surrounding the patient. He, or she, is old, frequently fat, often, when first seen, already suffering from hypostatic congestion of the lungs, which after a time may become an edema causing death. There is usually a suspicious redness over the sacrum, and the nurse, or family, complains that it is next to impossible to keep the patient clean, because of the protests that she makes at any attempts to change her position. The picture is one to make the most optimistic surgeon shudder. If the patient dies untreated the death will be regarded by the family as an act of God, and frequently as one for which they are most

grateful. Such a death is commonplace. There is no community that is not familiar with the story of more or less legendary great uncles and aunts who "broke their hips," and died after varying degrees of suffering. If the surgeon applies treatment other than the generally accepted ritualistic sandbag, particularly the proverbial instrument of torture known as the "plaster cast," and the patient dies, he and his treatment will receive full blame for the death. The relatives will forget the agony of the patient, and regret only that her presence could not have been vouchsafed them for a few weeks longer. Is it any wonder, then, that a surgeon should hesitate to apply a treatment of the soundness of which he may be theoretically convinced, but which very likely he has never seen applied? Can we blame him too severely for expatiating on the notorious unwillingness of such fractures to unite, of the necessity for making the patient as com-

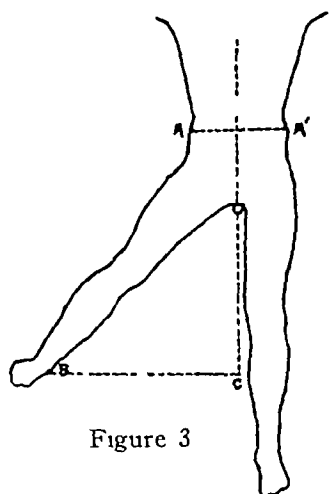


Figure 3

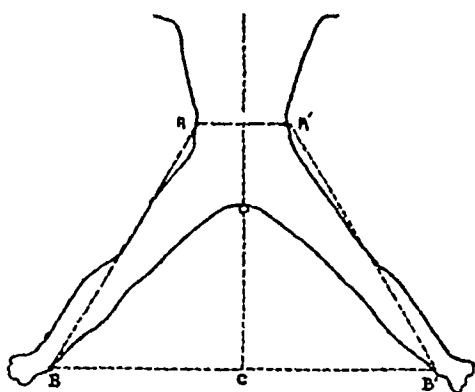


Figure 4

Fig 3—Abduction of the sound limb to the normal limit

Fig 4—With traction maintained, the affected limb is abducted to correspond to the normal. Angle $B'OC$ must equal angle BOC , distance $A'B'$ must equal AB .

fortable as possible, and of getting her out of bed immediately to avoid pneumonia? In such a course he is supported by tradition, and he will add to his reputation as a "sound conservative."

In this connection, I hope that I may not be accused of levity if I use the following incident as an illustration. During a clinic which I was holding on infantile paralysis in New York State I heard one physician say to another that a child in a far, outlying district had just died of "black measles." I asked what "black measles" were. "Why, Doctor," was the answer, "it's a peculiar disease we sometimes have around here. Only Dr. Smith's patients have it. He

makes the diagnosis, all the families hereabout know it's fatal, so when the patient gets no treatment and dies of 'black measles' everybody's satisfied "

The second cause for the failure to apply the abduction method is that when Dr Whitman originally described its theory³—its basic anatomic principles—he also described its application by the use of the long plaster-of-Paris spica. I am seriously inclined to believe that this was unfortunate. Had the treatment been described solely by anatomic demonstration and its practice left to the individual, the grasp of the theory might not have been overshadowed and interfered with by the difficulty of a particular method of its application. So great has this confusion become that I have frequently heard the abduction treatment referred to as the "plaster treatment." It is not a plaster treatment. The means of its application are a detail, and vary according to the individual predilections of its employers. Sir Robert Jones⁸ uses an abduction frame. Dr McGlannan⁹ of Baltimore includes both thighs. Dr Scudder⁷ of Boston puts the limb in a flexed position. Judet⁷ of Paris uses the "gouttiere de Bonnet." These are methods that are much at variance, but that are sound because those that employ them have a definite idea of what they are trying to do, and why they are trying to do it.

There is an impression current among the profession that anybody can apply plaster of Paris. The corollary of this proposition is that plaster of Paris is uncomfortable. As a matter of fact I know of nothing in surgery which requires more practice, or is more difficult, than to apply a comfortable plaster-of-Paris dressing. And of all plaster-of-Paris dressings there is none more difficult to apply properly than a long spica, extending from the axillae to the toes, in which the patient must live for a period of weeks. After having applied such a dressing, one has then to combat the obstinacy of the entire nursing profession. That profession, too, has its traditions, of which one of the most firmly grounded is that patients encased in plaster are as immovable as the Rock of Gibraltar, and must lie in changeless discomfort until they die of bedsores. Any suggestion that the patient be moved at all, much less turned on the face, is met by a gasp of horror. As a matter of fact, however, and I have even had this sheepishly admitted to me by a broken-spirited attendant, it is easier to turn a patient, even with the added weight of plaster, when turning does not cause him pain, than

8 Jones, Robert. *The Oxford Surgery*, New York, Oxford University Press, 1918, p. 805.

9 McGlannan, A. *Fracture of the Neck of the Femur*, Surg., Gynec. & Obst. **22** 287 (March) 1916.

when every movement causes discomfort, sometimes bordering on agony

Provided the plaster has been properly applied, it should be comfortable and strong enough to permit of the patient's being freely moved about. He should be turned on his face every day, as well as from side to side, and this constant shifting of position is the most certain preventive of bedsores.¹⁰ Unless the nurse's hand is exceptionally large, she will find it quite possible to introduce it under the plaster and give the back its daily massage.

The objection is being continually made that the "treatment is so confining." This is quite true, but I know of no treatment of what may be called a major fracture, that is not confining. Indeed, since the war, we have capable advocates of the treatment of all fractures of long bones by traction and suspension. At a recent lantern slide demonstration of this technic,¹¹ I heard one enthusiastic convert remark that "Dr. Blake's demonstration had sounded the death knell of the treatment of fractures by plaster of Paris." What those who object to the confining element of treatment really mean is that they fear to try any treatment at all, and, neglecting the fracture entirely, wish to get their patients up and about as soon as possible. This attitude is perfectly reasonable provided its advocates make it clear to themselves and their patients that they are abandoning all thought of functional recovery and are preserving for them a future of permanent lameness and discomfort.

As a matter of fact, in many cases, the treatment need not be exceptionally confining. A degree of activity is possible directly in proportion to the temperament—adventurous or otherwise—of the patient. I have already said that all patients should be turned on their faces daily for a varying period, and of course all patients should have the heads of their beds raised to avoid the danger of hypostatic congestion. From this as a minimum, one may proceed as far as having the patient up and out to drive. If the splinting apparatus be properly applied, movement causes no pain, and the difficulties of movement become purely mechanical and subject to the strength and ingenuity of the patient. One woman now under treatment at her own home, after remaining at the hospital for one week, had her husband sling a pole from the head to the foot of her

10 Whitman, Royal. The Abduction Treatment of Fractures of the Neck of the Femur, with Especial Reference to the Semireclining Posture and Changes in the Attitude in Its Application to Elderly Subjects, *Ann Surg* 53 489 (April) 1911.

11 Whitman, Royal. The Abduction Treatment of Fractures of the Neck of the Femur, *Med Rec* 97 585 (April 3) 1920.

bed, over which a rope was passed and made fast to the leg of the plaster. With this primitive block and tackle she was able to change her own position at will. Another energetic Jewish woman, aged 64, at the Hospital for the Ruptured and Crippled, insists on being propped up in a wheel chair every day. Insane patients, who could not be treated in any other way, have as a last resort been, as it were, boxed up in plaster of Paris by the abduction method and have made perfect functional recoveries. Sir Robert Jones, indeed, goes so far as to say, "Where hypostatic troubles may be expected, plaster of Paris has advantages over any kind of splint, for the patient need not be confined to bed."⁸

To quote again from the article which is serving for my text, speaking of the application of a plaster spica upon a pelvic rest, the points of support being the sacrum and the shoulders, the author says, "The vertebra [sic] are sagging in the middle with the spines projecting more than they naturally do. This factor explains the great discomfort frequently experienced and the fact that bedsores are not uncommon." If plaster, or any support, be applied in this position, the consequences to which the author alludes are to be expected. One must be most careful to guard against this by full extension of the thighs upon the pelvis, thus tilting the pelvis forward, and by manual support if necessary, or the insertion of a pad or pillow, to assure the maintenance of the normal lumbar lordosis. It is the flat back, the result of the sagging of the spine following prolonged confinement in bed, that is the cause of so much discomfort, and sciatic pain.¹² How much worse if the patient be immobilized in this position. The quotation is a perfectly justified criticism of an improperly applied support. I should imagine also that this danger of the flat back, obliteration of normal lordosis, would have to be particularly guarded against if the patient were put up with the thighs flexed on the pelvis.

A third reason for the failure of the general application of the treatment is the neglect of surgeons to carry out its elementary anatomic details. For this I confess I can find no satisfactory explanation. On one occasion, I demonstrated the application of the method on two patients to the interns of a general hospital, to their apparent understanding and satisfaction. A short time after, I returned to find two other patients to whom they proudly stated the method had been applied. The affected limbs were possibly in 15 degrees of abduction, the body portion of the plaster was so short that it dug into the

12 Goldthwait, J. E., and Osgood, R. B. *A Consideration of the Pelvic Articulations from the Anatomical, Pathological and Clinical Standpoint*, Boston M & S I 152 593, 634 1905

patients' short ribs, causing them continual discomfort, and the plasters had both broken at the groin. At times one might really be led to suppose that surgeons do not know what abduction is. This may be evidenced by Figures 5, 6 and 7, taken from a most interesting article¹³. Abduction is a motion taking place at the hip joint and not one of the patients photographed shows any abduction whatever. They are simulating abduction by tilting the pelvis. Nor do surgeons understand why abduction is important, and they are inclined to regard the insistence on the position of full abduction as an idiosyncrasy of a faddist. Full abduction is important for these reasons. It anatomically restores the alinement of the fractured bone and assures mutual pres-



Fig 5—Simulation of abduction by tilting of the pelvis. The patient shows no abduction whatever. (Illustration taken from an article by another author.)

sure of the fragments upon one another. Full abduction is necessary to assure internal splinting, by forcing the proximal fragment within the acetabulum, maintaining tension on the capsule, and bringing the trochanter in contact with the rim of the acetabulum. After the bone has united the patient can walk without a limp. A normal range of abduction is as essential to a normal gait as is that of flexion or extension. The secret of the indifference displayed toward this

13 Davison, Charles. Transplantation of Bone for Defects of the Head and Neck of the Femur, *Surg., Gynec & Obst* 29 142 (Aug) 1919

detail lies in the fact that surgeons are astonished and gratified to have such a patient walk at all. As a criterion of success to demand that he walk with comfort or without a limp would be regarded as chimerical.

Indeed, I am sorry to say that in the general literature on the subject, the clearest and most concise statement of why abduction is essential comes from a French author, Dr Judet:

Elle (traitement) doit viser à rétablir à la fois la forme et la fonction. Il est d'ailleurs reconnu aujourd'hui que la seconde ne peut être parfaite si la première est très déficiente.



Fig 6—Simulation of abduction by tilting of the pelvis. The patient shows no abduction whatever. (Illustration taken from an article by another author.)

Treatment should aim to reestablish, at the same time, form and function, it is, however, recognized today that the second cannot be perfect if the first is defective.

Evidently in France it is not considered a "crime to disturb impaction" with a view to the improvement of function, nor is the surgeon satisfied if he has succeeded in obtaining union with the bones in unsatisfactory position.

Another cause for failure lies in improper after-treatment. As Henderson⁴ says, in speaking of the cases in his series, "Good treatment had been instituted in a few instances, but for some reason it

was not prolonged enough" Here again surgeons at large do not seem willing to face the fact that weight should not be borne on the affected limb for six months after the injury This seemingly excessive caution is due to these reasons first, the slowness of repair of intracapsular fractures, second, the peculiar situation of the injury, the body weight falling directly across the line of fracture I suppose the reason for not considering these facts and for the tendency to allow early weight bearing with the consequent grave risk of refracture, or the development of the deformity of coxa vara, is that to

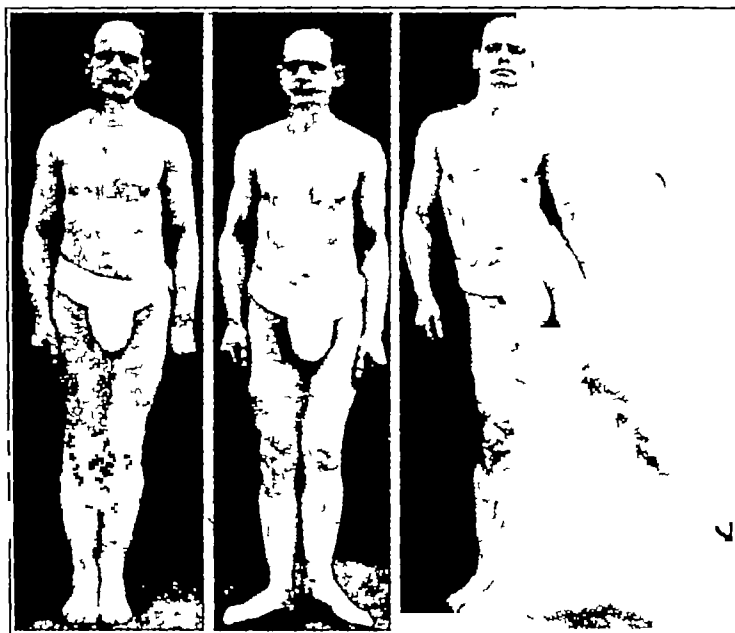


Fig 7—Simulation of abduction by tilting the pelvis The patient shows no abduction whatever (Illustration taken from an article by another author)

most people non-weight-bearing means lying in bed, or at least getting about on crutches This is not necessary, as the caliper hip splint will allow fairly comfortable locomotion¹⁴ It is possible to employ the Thomas splint for the same purpose, though it is not nearly so comfortable Even if neither of these methods is practicable, I think the average patient would prefer six months' inaction to a permanently damaged and probably painful limb

SUMMARY

The causes militating against the proper treatment of fracture of the neck of the femur would seem, then, to be these (1) the tremendous force of surgical tradition to the effect that any treatment

¹⁴ Whitman Royal A Treatise on Orthopedic Surgery, Ed 6 Philadelphia, Lea & Febiger, 1919, p 555

is useless, (2) the fact that the majority of such injuries occur in subjects that are not in any respect attractive to the surgeon, (3) lack of clear understanding of the anatomic principles of the abduction treatment, (4) the unfamiliarity of the average surgeon with the use either of plaster of Paris or the manufacture and application of other retention apparatus, (5) lack of appreciation of the necessity for the restoration of the normal form and structure of a bone if normal function is subsequently to be expected, and (6) a neglect of proper after-treatment, and the lack of insistence on detail

In a paper such as this, and in any inquiry into failure, it is very difficult not to seem hypercritical, and I can imagine many readers laying this aside with the impression that the emphasis throughout had been on criticism, and perhaps on criticism of individuals. I hope that such will not be the case. In any walk of life there are certain facts that must be faced, and one of the most glaringly unpleasant in the surgical world is the wretched lot of the average patient with a broken hip. None of the obstacles to failure that I have enumerated is insuperable.

No one, unless self-deluded or a liar, will pretend that a certain treatment can be applied in all cases, or that all patients may be cured. What I hope to see in the immediate future is the wider recognition of the fact that a fracture of the neck of the femur is a fracture like any other fracture, even though it often occurs in subjects that one would not be anxious to treat for any complaint whatever, also that the same standards of treatment and the same judgment of results should be applied to this fracture as to any other.

Surgeons can no longer shelter themselves behind the age-long superstition to which Sir Astley Cooper one hundred years ago did not subscribe, that intracapsular fractures of the neck of the thigh bone will not unite under any form of treatment. If they do not care to apply treatment in a given case they must explain to those concerned that the character of the patient makes it inadvisable to treat the fracture, not that the character of the fracture makes it inadvisable to treat the patient.

TWELVE CASES OF THROMBOSIS OF THE CAVERNOUS SINUS

FROM A STUDY OF FIFTY THOUSAND SURGICAL HISTORIES IN THE
JOHNS HOPKINS HOSPITAL *

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INTRODUCTION

Thrombosis of the cavernous sinus is a very rare condition. In 1902, Dwight and Germain¹ stated that only 182 cases had been reported, and in 1918, Smith² estimated the number reported as less than 300. Only eight cases were found by us in 50,000 of the surgical records of the Johns Hopkins Hospital from 1889 to 1919. This is only one case for every 6,250 patients. We are including in this report four other cases—two of these were on other services³ in the Johns Hopkins Hospital, and we are indebted to Surgeon-General Ireland, United States Army, for the privilege of reporting two other cases (Cases 11 and 12) which were seen by Dr. Chisolm while in the army during 1918 and 1919.

REPORT OF CASES

CASE 1—History—A colored laundress, aged 40, was admitted to the Surgical Service of the Johns Hopkins Hospital, May 15, 1899, complaining of a swelling of the jaw. The personal history was negative. The present illness had begun five weeks before with toothache. A tooth had been extracted following which the left jaw became painful and swollen. The symptoms gradually increased and the patient became restless and irritable. Four days before the patient had a chill and became drowsy. Two days before a large abscess in the left parotid region was incised.

Examination—On admission the temperature was 104 F and the pulse 144. Pus was draining from the incision over the left parotid region. Swelling extended to the anterior and posterior triangles of the neck. Through the incision a probe could be passed to the mastoid and posterior cervical region. The teeth of the lower jaw were loose, necrotic at the roots and bathed in pus.

* From the Surgical Clinic of the Johns Hopkins University Medical Department.

1 Dwight, E. W., and Germain, H. H. Thrombosis of the Cavernous Sinus, with Report of Four Cases Including One Cranial Operation, Boston M & S J **146** 456, 1902.

2 Smith, D. Cavernous Sinus Thrombosis, with Notes of Five Cases. Arch Ophth **47** 482 (Sept.) 1918.

3 We wish to thank Professors Williams and Howland for the privilege of reporting Cases 7 and 10 respectively.

A few faint rales were heard at the bases of both lungs. There was a faint systolic murmur in the pulmonic area. Urine examination revealed specific gravity, 1.022, acid, a trace of albumin, a few white and red blood corpuscles, a few hyaline and granular casts, bile +, and no sugar. Blood culture disclosed no growth. On lumbar puncture, 34 cc of a turbid straw colored fluid was withdrawn which contained leukocytes and a few extracellular diplococci. Cultures revealed a pneumococcus.

Course in Hospital—There was a septic temperature ranging between 99.2 and 104.6 F. May 15, the patient was unconscious, there were marked swelling of the left jaw and edema of the face, especially of the right eyelids, right exophthalmos, edematous conjunctivae and rigidity of the neck. There was a friction rub in the right axilla. Respirations were rapid and noisy. May 17, there was increasing bulging of the right eye with edema of the surrounding tissues. May 18, coma and increased swelling of the face were present. No Kernig sign was elicited. Pulse was small and irregular, temperature was 104 F. The patient died.

Necropsy—There was an operative wound for parotid abscess following alveolar abscess, with extension to the temporal and sphenoidal regions. There was basilar meningitis with hemorrhages into the brain, meninges and spinal cord. Cloudy swelling of viscera was present. (No note on venous sinuses of skull or paranasal sinuses.)

Etiology—This was evidently a case of cavernous sinus thrombosis with an alveolar abscess as the primary focus, the infection involving the cavernous sinus through the pterygoid plexus. The organism was a pneumococcus. The duration of the disease was two days after the onset of eye symptoms.

CASE 2—History—A boy, aged 5 years, was admitted to the Surgical Service of the Johns Hopkins Hospital on Aug 8, 1900. The personal history was negative. The present illness began two weeks before when he fell, striking his forehead. The injury was apparently trifling. A few hours later a swelling appeared above the left eye, but this entirely disappeared in a few days. One week before, he suddenly became restless and was delirious within a few hours. There were nausea and vomiting, and for the last few days the head had been retracted. The left upper eyelid became much swollen.

Physical Examination—On admission the temperature was 104 F, the pulse, 110. The patient was well developed, and showed a flaccid paralysis of the right leg and arm and of the left side of the face. There were restless movements of the left arm and leg and marked retraction of the head. There was marked exophthalmos on the left side with edema of the lids, the left pupil was widely dilated and immobile. The fundus showed optic neuritis; there were no hemorrhages. The right eye was normal. The nose showed a blood clot on the right side but no purulent discharge. The ears were normal. Blood count revealed white blood corpuscles, 41,000. No specimen of urine was obtained. Culture of spinal fluid disclosed *Staphylococcus aureus*.

Operation—Aug 8, 1900, the left orbital abscess was incised and drained. Thick yellow pus was obtained which on culture showed *Staphylococcus aureus*. Exploratory craniotomy was performed in the left frontal region, no brain abscess was found.

Course in Hospital—Temperature was septic in type. The day following admission, the general condition was much worse and there was edema of the right eyelids. On August 10, this edema had increased. Temperature was 107 F. There were convulsive and athetoid movements of the right arm and leg.

On August 11, the parents insisted on removing the child from the hospital. The temperature was 108.3 F. The child died shortly after reaching home. Necropsy was not obtained.

Etiology—This was a case of left orbital abscess following injury. The infection reached the left cavernous sinus through a thrombosis of the ophthalmic vein and extended to the right cavernous sinus through the circular sinus. There was septic basilar meningitis with softening in the lower section of the pons giving rise to the crossed type of paralysis—right sided hemiplegia and left sided facial paralysis. The organism was *Staphylococcus aureus*. Duration of disease was about ten days.

CASE 3—History—A farmer, aged 32 years, was admitted to the Surgical Service of the Johns Hopkins Hospital, Oct. 31, 1909. His skull had been fractured in the right temporal region two years before. For the past two months he had been feeling bad, showing a slight elevation of temperature and occasionally complaining of left sided headache. The onset of the present illness had been sudden, occurring four days before with pain over the left eye and on the left side of the head, nausea and a chill, with a temperature ranging between 102.5 and 105 F. The pulse ranged between 60 and 80. Later there was a painful swelling in the left temporal region and cheek. Prior to admission to this hospital, the left mastoid had been explored and found normal.

Physical Examination—On admission the temperature was 104.6 F and the pulse 80. The patient was mentally dull and irrational. There was profuse sweating of the right side of the body. The right abdominal reflex was absent. There were enlarged submaxillary glands on the left side. Pain was felt in the neck on movement of the head. The entire left side of the face was swollen, there was slight facial weakness on the right side. There was no tenderness over the sinuses. Swelling of the eyelids was more marked on the left, the left external rectus was weak. Fundi showed no choked disk. There was fulness of the veins in the fundus of the right eye. The teeth were in good condition. The right tonsil was enlarged and covered with purulent exudate. There was an exploratory mastoid wound on the left. Blood count revealed white blood corpuscles, 32,000. Culture of spinal fluid disclosed *Staphylococcus aureus*. No specimen of urine was obtained.

Operation—Oct. 31, 1909, the left mastoid wound was explored. The lateral sinus was exposed and found normal.

Course in Hospital—Temperature was continuously elevated, between 104.6 and 105.4 F. The pulse varied from 80 to 130. Nov. 1, 1909, double exophthalmos was present, the conjunctivae were very edematous, especially the right, the pupils were dilated and reacted sluggishly to light. The fundi showed no choked disk. There were marked tortuosity and distention of the retinal veins. The veins of the eyelids and forehead were distended, giving rise to a purplish color. The tongue was swollen, breathing was labored, temperature was 105 F. Tracheotomy was performed but without effect. Death followed.

Necropsy—This revealed purulent thrombosis of both cavernous sinuses, more marked on the left side, thrombosis of the left lateral sinus, empyema of the left antrum, pus extending along the third branch of the fifth nerve through the foramen ovale to the left cavernous sinus, abscess and necrosis of the posterior wall of pharynx and purulent meningitis.

Etiology—There was empyema of the left antrum with extension of the infection through the pterygoid plexus to the left cavernous sinus. Unilateral sweating was an interesting feature. The duration of the disease was five days. The organism was *Staphylococcus aureus*.

CASE 4—History—A woman, aged 34, was admitted to the Surgical Service of the Johns Hopkins Hospital on April 28, 1910, complaining of an "infected face" The personal history was negative The present illness began four months before with inability to open the mouth and swelling of the right side of the face A tooth in the right upper jaw had been extracted a few days before The swelling soon extended to the right side of the neck and the right mastoid region Since that time the patient had been under treatment constantly The patient had undergone five operations (1) a tooth was extracted, the gum was incised, no pus was found, (2) an incision was made in the right temporal region followed by free drainage of pus, (3) an incision was made around the outer canthus of the right eye, three weeks later, no bone involvement was found, (4) an incision of the right side of the face from the hair line to the jaw was made one month later, (5) the right orbit was explored, no pus was found The case was diagnosed as septic thrombosis

Physical Examination—On admission, the temperature was 101 F The patient was pale and anemic A few râles were heard in both lungs A definite Kernig sign was elicited Two sinuses were present in the neck just below the angle of the jaw on the right side A large granulating wound covered with pus involved the entire right side of the face, into which opened a discharging sinus leading to a cavity under the eye. There was marked edema of the right eyelids and conjunctiva There was a fluctuating swelling above the right ear Examination of the mouth was unsatisfactory as the patient could part the teeth only 1 cm The urine was negative A culture of pus from the facial wound revealed *Staphylococcus aureus* The Wassermann reaction was negative

Course in Hospital—At first, the patient improved under local treatment of the face May 9, there was a choked disk of the right eye May 17, fundus of left eye showed veins, full and tortuous, disk clear, media hazy right eye, veins, tortuous Considerable right exophthalmos was present with dilatation of veins of eyelids and forehead May 18, there was considerable left exophthalmos

Operation—The right temporal region was explored The dura was exposed and found normal The right antrum was explored and found normal May 19, a blood culture revealed no growth May 24, fundi showed double choked disk Thrombosed left lateral sinus was exposed, left jugular vein was ligated and clots from the lateral sinus were removed May 26, the patient died Course in the hospital extended over a period of four weeks, during which time the patient had a septic temperature ranging from 96 to 104.2 F

To recapitulate, there was extensive infection of the right side of the face, presumably from a right upper molar tooth, which improved under local treatment There was low grade choked disk The right temporal region and right antrum were explored Infection from a tooth spread to the pterygoid region and thence to right side of the face and through the pterygoid plexus to right cavernous sinus Exophthalmos subsided somewhat, but later the condition became worse The patient was delirious at times There was a progressive rise of temperature Crowe sign⁴ was positive on the left side The left jugular vein was ligated and lateral sinus explored through mastoid (Not infected) Thrombus extended down to the point where the jugular was ligated Patient was unconscious and grew progressively worse Respirations were irregular and pulse was weak Crowe sign was positive on the right May 25 (day after left jugular ligation) Death occurred May 26, 1910

4 Crowe, S J Bull Johns Hopkins Hosp 23 321-323, 1912

Necropsy—This revealed the following (1) abscess, right orbit, (2) right temporal lobe abscess, (3) thrombosis both lateral sinuses, recent in right, (4) thrombosis, anterior two-thirds of superior longitudinal sinus, and (5) diffuse purulent meningitis. No note was made on cavernous or paranasal sinuses.

Etiology—Dental infection extending by way of the pterygoid region to the face, and from the pterygoid plexus to the right cavernous sinus. Thrombosis extended to the left cavernous sinus, thence to left lateral sinus and to the left jugular vein. Later the superior longitudinal and right lateral sinuses became thrombosed. Duration of disease was more than one month after eye signs first appeared. The organism was *Staphylococcus aureus*.

CASE 5—History—A colored bartender, aged 24, was admitted to Johns Hopkins Hospital, May 27, 1910, complaining of pain and swelling of the left eye and left side of the face. He had had frequent colds, two soft chancres, two and one-half years before, otherwise the personal history was negative. The present illness began with a cold in the head two weeks before. Nine days before admission it had "settled in his eyes." Since then fever, chills, sweats, pain in the left eye and left side of the head and neck had been present. He had vomited four or five times. There was increased swelling of the left eye, which had been swollen shut for two days.

Physical Examination—On admission the temperature was 103 F, and the pulse 114. A few fine rales were heard on both sides, front and back. There was a soft systolic murmur over the pulmonic area and retromanubrial dulness. There was marked swelling of the left eye, including particularly the upper lid, and the left cheek. The forehead and left side of the head were swollen. There was tenderness over the left mastoid. Blood count revealed white blood corpuscles, 6,300. The Wassermann reaction was negative. Blood culture revealed *Streptococcus pyogenes*. Urine examination was positive for albumin, and revealed no sugar. Bile was present.

Course in Hospital—There was a continuously elevated temperature of from 103 to 106 F. May 28, the left eye was more swollen, edema of the face was more marked.

Operation—The left supraorbital abscess and the scalp were incised and drained, thin pus was obtained from both. May 29 the patient was stupid, restless, unable to swallow and suffered constant pain in the head. May 30, he died.

Necropsy—This revealed empyema of both antrums and of the left ethmoidal and sphenoidal cells, thrombosis of the left cavernous sinus, abscess of the left orbit and left side of the face, acute purulent meningitis, extensive bilateral pneumonia with gangrene of both lungs, pulmonary edema and acute diffuse nephritis.

Etiology—Polysinusitis with (1) left sphenoidal cells as the focus giving rise to a primary unilateral cavernous sinus thrombosis, or (2) the left ethmoid infection may have been responsible for the orbital abscess, thus resulting in thrombosis of the ophthalmic veins with extension to cavernous sinus. There was metastatic pulmonary involvement. The duration of the disease was eleven days. The organism was a streptococcus.

CASE 6—History—A child, aged 4 years, admitted to the Johns Hopkins Hospital Jan 15, 1912 (Fig 1), had always been healthy except for three or four epileptiform attacks during the last six months. The present illness began

one week before with toothache. Two days later the right side of the face and the right eye became swollen. Two days before admission the left eye also became swollen, so that both eyes were closed. There was apparently no pain.

Physical Examination—On admission the temperature was 103 F and the pulse 120. The patient was rather stuporous, there was a sweetish odor to the breath. General examination otherwise was negative. The eyes showed double exophthalmos. The upper lids were edematous, so that the eyes were swollen shut. The eyelashes were matted together with exudate, the conjunctivae were edematous. Fundi showed tortuous vessels. There was no choked disk on either side. There was edema of the forehead and bridge of the nose, fulness of the right cheek and right submaxillary region. The cervical glands on both sides were considerably enlarged. The ears were negative. The teeth were dirty and the mouth foul. There was a discharge of pus in the left side of the mouth not definitely localized. Blood count revealed white blood corpuscles, 15,000, hemoglobin, 86 per cent. Urine examination disclosed albumin, positive, acetone, positive, and diacetic, positive.



Fig 1 (Case 6)—Patient, tenth day of the disease, showing the marked double exophthalmos and edema of the lids.

Course in Hospital—Temperature ranged between 101 and 106.6 F, not septic in type but a rather constant elevation. January 19, condition was unchanged. The child was perfectly conscious. There had been no vomiting since admission. January 21, the patient was more restless, the pulse was weaker, Kernig sign was negative. There was questionable rigidity of the neck. Exophthalmos was increased and lids were everted. January 23, condition had gradually grown worse, the patient was stuporous and refused food. The eyes were more prominent, the face paler and cyanotic. January 24, the pulse was very weak and rapid, respirations were rapid and labored. The extremities were cold and cyanotic. There was no Kernig sign nor rigidity. Coarse râles were heard over both lungs. The child died quietly at 6 p. m. No necropsy was obtained.

Etiology—This was a case of septic thrombosis of cavernous sinuses, probably secondary to an alveolar abscess. There were no evidences of meningitis or pulmonary involvement. The duration of the disease was thirteen days. The organism was not determined.

CASE 7—History—A housewife, aged 41, was admitted to the Obstetrical Service of the Johns Hopkins Hospital Oct 24, 1915 (Fig 2). Her general health had been good. She had six children and a miscarriage in 1904 at six

months. A laparotomy had been performed five years before. The patient was nine months pregnant. Two days before admission the membranes ruptured prematurely and she developed a fever. The temperature was 104 F. October 25, operative delivery was performed under ether and chloroform, a craniotomy was performed on the dead child. The patient continued to have a daily elevation of temperature between 104 and 106 F. November 3, urine examination revealed albumin, + + +, many white blood corpuscles. Urine culture revealed an organism of the colon-typhoid group. Uterine culture was negative. Wassermann



Fig 2 (Case 7) —Patient on third day of the disease, showing the exophthalmos and edema of the lids, more marked on the right side

reaction was negative. During the night of November 13, three weeks after admission, the patient complained of pain over the right eye, and the following morning there was swelling around the eye with marked photophobia.

Physical Examination—On Nov 14, 1915, the lungs were clear. Heart examination revealed a systolic murmur at the apex, transmitted to the axilla. There was a scarred cervix uteri. No glandular enlargement was present. Exophthalmos on the right side was marked, the bulb was practically immobile. There was edema of the eyelids and photophobia. The right pupil was round and contracted. Vision was lost except for light perception. Left eye was nor-

mal Ophthalmoscopic examination revealed on the right side an exudate on the lens capsule and a turbid vitreous Fundus could not be seen Blood count showed white blood corpuscles, 20,000, red blood corpuscles, 3,700,000, hemoglobin, 70 per cent Blood culture revealed a pneumococcus November 15, exophthalmos had increased on the right side, there was beginning exophthalmos on the left side The conjunctivae were injected and edematous The cornea was steamy November 16, there was some consolidation of the right lung, and diffuse musical rales Pneumonia developed November 17, deafness developed, together with signs of basilar meningitis Kernig's sign was positive, knee kicks were ++, there were beginning opisthotonos and muscular twitchings The Babinski sign was negative November 18, pulmonary consolidation was increasing, meningeal signs were more marked, the heart was dilated The temperature was 106.6 F The patient died at midnight The temperature was of the septic type throughout, ranging from 98 to 107 F

Necropsy was not obtained

Etiology—After running a septic temperature for three weeks after delivery (accompanied by evidence of infection of the urinary tract), the patient developed signs of thrombosis of right cavernous sinus, and a blood culture taken the same day revealed a pneumococcus Two days later signs of lobar pneumonia developed, followed the next day by signs of basilar meningitis Pneumococcus puerperal infection is very rare It is possible that there was a metastatic involvement of the cavernous sinuses during the course of a general pneumococcic septicemia, but it is more probable that an unrecognized right sphenoidal or ethmoidal infection extended to the right cavernous sinus The duration of the disease was five days after the development of the eye signs

CASE 8 — History — A schoolboy, aged 12 years, was admitted to Johns Hopkins Hospital, Aug 5, 1916, complaining of swelling of right eye and right side of face (Figs 3 and 4) The boy had had the usual diseases of childhood without complications There had been an injury to the nose (possible fracture) six months before Two days before the present illness he had been swimming and diving in a public swimming pool The present illness had begun five days before admission with headache, malaise, fever and nausea The right eye became swollen and there was diplopia On the third day, the headache practically disappeared, but there was marked tenderness about the right eye No nasal discharge was noticed

Physical Examination—On admission, Aug 5, 1916, the temperature was 103.4 F, the pulse was 100 General examination was negative The Kernig sign was negative The right eye was closed, the lids swollen, red and tender The conjunctiva was blood-shot, there was exophthalmos The pupils reacted to light Fundi showed full vessels on the right No choked disk was present The left eye was normal The right side of the face was swollen and the glands at the angle of the jaw on the right were enlarged On the right side of the nose there was deflection of the septum, congestion of the mucous membrane and profuse purulent discharge coming from the middle meatus The left side was normal Evidently there was an acute right ethmoidal infection A roentgenogram of the sinuses revealed the frontal sinuses and antrums clear There was trismus, the teeth could be parted only 1 cm The right upper canine tooth was loose The ears were negative Urine examination revealed albumin plus, no casts Blood count revealed white blood cells, 23,000 Blood culture showed no growth The Wassermann reaction was negative Culture of pus from right nostril showed *Staphylococcus aureus*



Fig 3 (Case 8) —Patient on sixteenth day of the disease The swelling and exophthalmos on the right are beginning to subside, swelling of the left side of the head and neck is the result of the thrombosis of the jugular vein in addition to that of the cavernous sinus

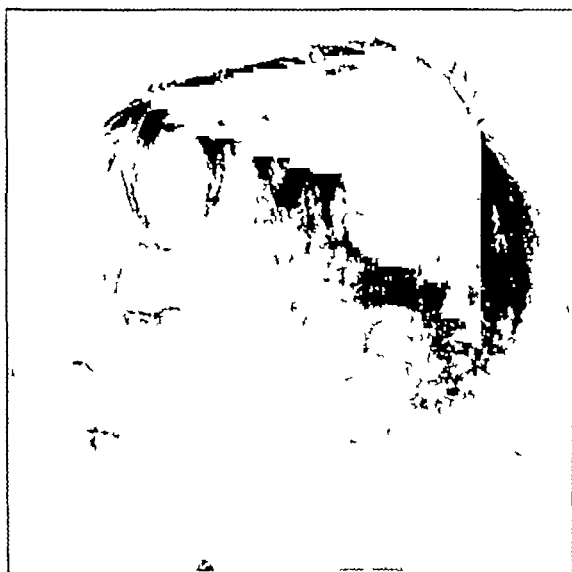


Fig 4 (Case 8) —Patient on sixteenth day of the disease, showing the marked exophthalmos and edema of the eyelids of the left eye

Course in Hospital—August 6, the patient was delirious. The Kernig sign was plus. Stiff neck and general hyperesthesia were present. There was incontinence of urine.

August 7, he was noisy. There was incontinence of urine and feces. The right upper canine was extracted, pus was found at the root. Culture revealed *Staphylococcus aureus* and a nonhemolytic streptococcus. The right antrum was punctured and pus was obtained.

August 8, there was less swelling of the right eye, beginning swelling of lids and exophthalmos on the left side.

August 10, he was noisy. Eye signs on the left were increased, swelling extended down to the left side of the neck.

August 11, he was mentally bright. The Kernig sign was still positive. The neck was stiff. There was tenderness over the neck and entire head. Edema was increasing. A diagnosis of thrombosis of both cavernous sinuses, extending down into the jugular vein on the left side was made.

August 12, the right eye could be opened. The pupils reacted to light. The vision was good. Extra-ocular movements were good, although there was still some protrusion of the bulb. Ophthalmoscopic examination revealed right veins full, disk outline hazy. There was a low grade choked disk. The left could not be seen. White blood cells numbered 27,600.

August 13, he was drowsy and irritable. The swelling extended over the left side of the head, the scalp veins were full. General hyperesthesia. Nasal discharge was decreasing. He complained of pain in the left ear. Both drums were normal. Lumbar puncture revealed fluid, clear, tension not increased. Cell count disclosed 1 per cm (all mononuclears). Culture showed no growth.

August 14, the right middle turbinate was infracted. There was discharge of pus. The nasal mucosa on the right side was being shrunk several times daily by local application of epinephrin.

August 15, he complained of pain in the left knee which was tender and held in flexed position, extension was painful. Kernig's sign was negative. There was less rigidity of neck muscles. Urine examination was positive for albumin, there were many casts.

August 16, blood culture revealed *Staphylococcus aureus*, five colonies per c c.

August 17, both eyes could be opened. Swelling and exophthalmos were less. There was no diplopia. Extrinsic ocular movements were good. The pupils reacted. Ophthalmoscopic examination revealed low grade double choked disk. The left knee symptoms were acute. There were redness, swelling and local elevation of temperature. He complained of pain in the chest. Signs of bronchopneumonia (probably a pulmonary infarction) developed.

August 19, there was swelling and fluctuation in the left frontal region and osteomyelitis of skull.

August 20, there was evident bronchopneumonia with a friction rub in the left axilla.

August 21, pain and tenderness developed in the left mastoid region. The left drum was injected, not bulging. Blood count revealed white blood cells, 17,500. He was given *Staphylococcus aureus* vaccine, 25,000,000.

August 23, the general condition was improving. Acute suppurative otitis media developed on the left side. The left knee joint was aspirated, 25 c c of purulent fluid was obtained, culture revealed *Staphylococcus aureus*. Ophthalmoscopic examination revealed choked disks though less marked. *Staphylococcus aureus* vaccine, 50,000,000, was given.

August 24 roentgenograms revealed mastoids clear, left knee, destruction of patella, marked periarticular swelling, lungs, mediastinitis, spotty infiltration patchy consolidation at right apex, enlarged mediastinal glands, sinuses, marked clouding of right antrum and ethmoids and left frontal

August 25, urine examination revealed albumin, plus, red blood cells and white blood cells and numerous granular casts Urine culture disclosed *Staphylococcus aureus*

August 27, there was less tenderness over the left mastoid Otitis media was clearing up Left knee was again aspirated No fluid was obtained General hyperesthesia was no longer evident Blood culture revealed *Staphylococcus aureus* one colony per cm *Staphylococcus aureus* vaccine, 75,000,000, was given

August 30, right antrum was punctured and irrigated, the fluid was clear Lung signs were clearing up, there was no friction rub

September 3 left otitis media had entirely cleared up, drum looked practically normal There was no mastoid tenderness Left knee was still swollen and painful *Staphylococcus aureus* vaccine, 100,000,000, was given

September 4 blood count revealed white blood cells, 15,000 Blood culture revealed no growth

September 9, there were dilated veins over the whole scalp, especially on the left side There was swelling in the left temporo-parietal region Ptosis and occasional internal strabismus were present on the left Cultures of the urine revealed *Staphylococcus aureus*

September 10, there was reappearance of swelling of eyelids on the left side (which however, disappeared again within two days)

September 13 *Staphylococcus aureus* vaccine (autogenous, from cultures of the urine), 100,000,000, was given

September 16, the temperature was normal for the first time, prior to this the patient had been running a septic temperature, ranging from 97 to 104 F, with apex of the curve gradually coming down

September 18, *Staphylococcus* vaccine (autogenous), 150,000,000, was given Ophthalmoscopic examination revealed disk outline still hazy, especially nasal margins, more marked on the right side

September 21, a fluctuating swelling in left parietal region appeared, which was aspirated Pus was found Culture revealed *Staphylococcus aureus*

September 24, left knee was still swollen, a few cc of bloody fluid was aspirated from the joint Blood culture revealed no growth Urine examination revealed albumin, 0, casts, + Roentgen rays revealed left knee same as above, extensive osteomyelitis of the skull involving the left side, giving a worm-eaten appearance to the bone

October 1, several additional areas of fluctuation had appeared over the left side of the head

October 3, there was a discharging sinus of the left knee Urine examination disclosed albumin, 0, casts, 0

October 9, operation was performed under light ether anesthesia Multiple incisions were made and sequestrectomy was performed for osteomyelitis of the skull, on the left side The sinus of the left knee joint was enlarged and a portion of the patella was removed The patient stood the operation well and following this showed steady improvement for the next six weeks

Nov 24, 1916, the patient was discharged from the hospital The general condition was excellent, he felt strong and well There had been no eleva-

tion of temperature whatever for the last two weeks. The eyes were entirely normal in all respects. The ears were normal. There still was a small amount of mucoid discharge from the nose on the right side. The knee was in a cast, he walked with crutches. There was one small discharging sinus near the hair margin in the left frontal region, other scalp wounds entirely healed (Figs 5 and 6).

Comment—An acute ethmoidal infection on the right, acquired by diving in a public swimming pool, led to a septic thrombosis of the right ophthalmic vein and right cavernous sinus. There was extension of the thrombosis to the left cavernous sinus, signs of which appeared eight days later, and into the left jugular bulb and internal jugular vein probably by way of the inferior petrosal sinus. Low grade *Staphylococcus aureus* septicemia developed with metastatic involvement of the lungs, left knee joint, kidneys and left half of skull. There were signs of meningeal involvement, but the spinal fluid was clear. Acute suppurative otitis media, left, appeared as a later complication. The pulmonary and renal signs cleared up rather rapidly. The bone metastases were treated surgically. A surgical operation directed at the primary focus was advised at an early stage of the illness, but the parents were loathe to consent and it was not urged. The local treatment consisted in irrigation of the right antrum on two occasions, infraction of the middle turbinate and frequent shrinking of the nasal mucosa on the right side to promote drainage of the infected sinuses. At first, a stock and later an autogenous *Staphylococcus aureus* vaccine was used. All the other treatment was symptomatic. Positive cultures of the infecting organism were obtained from the primary focus, the blood, the urine, the left knee joint and the osteomyelitic foci in the skull. The eye signs had practically disappeared within three weeks after onset, but there was a reappearance on the left side three weeks later, which, however, was slight and lasted only two days. The dilatation of the scalp veins gave evidence of the establishment of a collateral circulation. This was more marked on the left side, and it was on this side only that the osteomyelitic foci appeared, probably as the result of the septic emboli coming direct through this collateral circulation. Coincident with their development occurred a temporary reappearance of the eye signs on the same side. Trismus was noted in this case.

Subsequent History—The patient returned repeatedly to the orthopedic dispensary for treatment of the knee, and to the ear, nose and throat dispensary for observation. He was last seen in May, 1920, at which time the findings were. General health was excellent, he was working but was irritable and had lost fourteen different positions during the last six months. He walked with a limp due to an ankylosis of the left knee and a slight shortening of the left leg. Roentgen-ray examination of the left knee, May 18, 1920, revealed fibrous ankylosis, the patella and femur being fixed by bone. Scalp wounds were entirely healed and covered by hair. The right eye was normal in appearance, the left showed slight protrusion of the bulb. The lids were slightly bluish and puffy. The fundi were normal, the ears were normal. The nose showed deflection of the septum, and a small amount of discharge on the right side. The right antrum was dark on transillumination, other sinuses were clear. There had been no headaches. The mouth showed a small discharging sinus in the gum above the right upper canine tooth. The throat was negative. An indefinite mass was made out in the neck on deep palpation of the left side in the region of the internal jugular vein. Crowe's sign was positive for the left side, indicating nonpatency of the left jugular vein. Evi-



Fig 5 (Case 8) —Patient, May 2, 1917, about six months after discharge from the hospital, showing the slight prominence of the left eye and slight puffiness of the lids

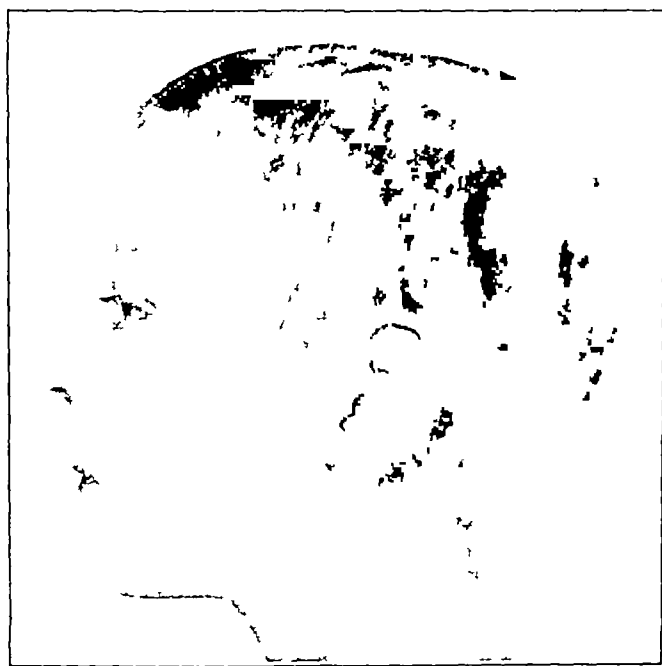


Fig 6 (Case 8) —Patient, May 2, 1917, about six months after discharge from the hospital, showing the scars at the points where the osteomyelitic foci in the skull were drained

dently the thrombus in the left jugular had become organized, leading to permanent occlusion of that vein. A trifling enlargement of the scalp veins was still evident—apparently the thrombus in the right cavernous sinus had been absorbed or had become canalized, while the left cavernous sinus had probably remained occluded. The visual fields are shown in Figure 7.

CASE 9—History—A housewife, aged 24 years, admitted to the Surgical Service of the Johns Hopkins Hospital, May 6, 1918, at 11 p. m., complaining of “sore eyes” (Fig. 8), had had the usual diseases of childhood, and acute tonsillitis six months before. She had “nasal catarrh.” Her general health was good. The present illness began six days before when the patient noticed

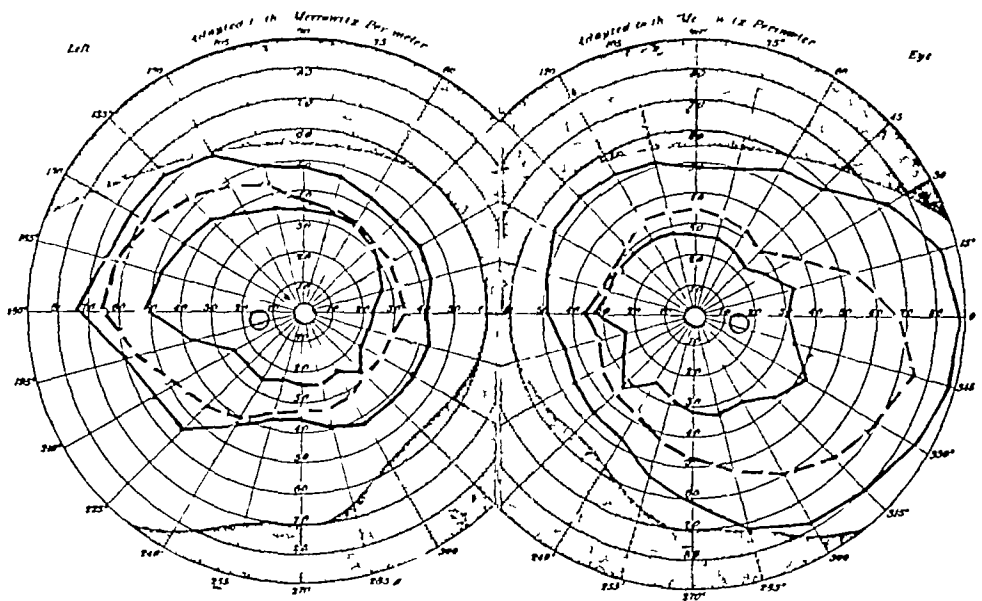


Fig. 7 (Case 8)—Visual fields, May 4, 1920, showing a definite contraction of the left field.

an inflamed area in the right side of the nose. She had fever, and the right eye gradually became affected. On the third day, there was marked swelling and discoloration of the eyelids, gradual protrusion of the eye, loss of vision and inability to move the eye. On the fourth day an abscess of the anterior nares was lanced, blood was obtained, but no pus. The left eye then became involved in the same way as the right. On the sixth day the neck became stiff. There has been headache from the first, generalized, but involving more particularly the top and back of the head. There had been fever but no chills.

Physical Examination on Admission—The temperature was 103.4 F, the pulse 110. Both jugulars were apparently patent. There was rigidity of the neck muscles. Knee kicks were sluggish. Kernig's sign was negative. Babinski's sign was negative. The eyes showed marked double exophthalmos with edema and swelling and redness of the surrounding tissues extending to temporal region. The conjunctivae were greatly injected. The pupils were unequal, the left was irregular and reacted sluggishly. Ophthalmoscopic examination demonstrated right, choked disk, congested and pulsating veins, left, not well seen on account of extreme photophobia. Herpes was present around the anterior nares. The left side of the nose was normal, the right side showed a crusty discharge.

The inferior turbinate was congested and ulcerated. The sinuses showed no tenderness. The right antrum was dark on transillumination, the left was fairly clear. The frontal sinuses could not be clearly seen because of swelling. Nasopharyngoscopic examination demonstrated the orifices of the posterior sinuses to be clear. The ears were negative. The throat was negative. Blood count revealed white blood cells, 19,000. Urine findings were albumin, + + +. Blood culture disclosed *Staphylococcus aureus*, twenty colonies per cc. On lumbar puncture 30 cc of turbid fluid was removed. Tension was not increased. Cell count numbered 1,500, mostly polymorphonuclears. Pellicle formed after three hours' standing. Culture demonstrated *Staphylococcus aureus*. Roentgen-ray reports were skull showed nothing abnormal, sinuses clear.



Fig 8 (Case 9)—Patient on the fourth day of the disease, showing the extreme exophthalmos and swelling of the eyelids

Course in Hospital—On the morning following admission, the right antrum was punctured and irrigated and a small amount of flaky material was washed out. On the afternoon of the same day, a right external ethmoid operation was performed.

Findings at Operation—Ethmoid cells were filled with polypoid tissue. Culture revealed *Staphylococcus aureus*. The sphenoid was clear. A small subcutaneous pus pocket was found over a necrotic area in the lacrimal bone. May 8, the patient's condition was much worse. She was comatose, there were stertorous breathing, carphologia and rigidity of muscles of the extremities and neck. Kernig's sign was positive. Lumbar puncture revealed turbid fluid with the same characteristics as given above. At 11 p m Cheyne-Stokes respirations developed. Shortly after midnight she vomited and died a very few moments later. During the stay in the hospital the temperature ranged between 100 and 104 F. Necropsy was not obtained.

Etiology—This was a case of right chronic ethmoidal infection with the development of an acute infection of the right ala nasae, which was incised. The infection traveled from the veins, draining the ala nasae to the ophthalmic vein and thence to the right cavernous sinus. A septic thrombophlebitis of the angular vein was probably responsible for the pus pocket found over the lacrimal bone. Symptoms of thrombosis of the left cavernous sinus appeared about twenty-four hours after those on the side first affected. There was an associated septic basilar meningitis and a toxic nephritis. *Staphylococcus aureus* was obtained from the right ethmoid region, the blood and the spinal fluid. The duration of the disease was eight days after onset of the superficial infection and six days after development of the first eye signs.

CASE 10—History—A child, aged 22 months, admitted to the Johns Hopkins Hospital, June 23, 1918 (Fig 9), had been treated at the Harriet Lane Dispensary in June and July, 1917, for acute otitis media, cervical adenitis and



Fig 9 (Case 10)—Patient on the fourth day of the disease the signs are more marked on the left side as the left cavernous sinus was the first to become thrombosed.

peritonsillar abscess. She had been under observation at intervals since that time for regulation of feeding. Two weeks before the onset of the present illness she had measles, from which she recovered and had been up for several days when a swelling of the left side of the face and the left eye appeared two days before admission. The following day the swelling seemed to decrease but on the day of admission it became more marked and began to involve the right eye also. She had had fever for three days, slight cough but no vomiting.

Physical Examination—On admission the temperature was 105.2 F, the pulse 204, and respirations, 48. She was dull and irritable. There was general glandular enlargement. The lungs showed consolidation of the right lower lobe and a marked friction rub. The left lower lobe showed the same signs to a less extent. Kernig's sign was positive. Knee kicks were not obtained. There was no stiff neck. There was marked tache cerebrale over the left parotid region. The eyelids were edematous, especially the left. Double exoph-

thalmos was present. The eyelids were red and tense. There was a small amount of purulent discharge in the conjunctival sacs, a smear made from this was negative. The left side of the face was edematous and injected, particularly in the parotid region, and the edema extended down into the neck to the left shoulder and clavicle. There was a slight nasal discharge. The ears were normal. The throat was slightly injected, otherwise it was normal. The teeth were negative. Blood count revealed white blood cells, 23,500. Von Pirquet's sign was negative. Not enough blood was obtained for blood culture. Lumbar puncture demonstrated cloudy fluid under increased pressure. There was a film format on after standing fifteen minutes. Smears showed a few organisms suggesting pneumococci, culture, unfortunately contaminated. No specimen was obtained for urinalysis.

Course in Hospital—June 29, the eyes were more bulging, the left lids were tense and shiny, the neighboring veins were dilated. There was a marked urticarial eruption over the entire body. June 30, the left upper arm and shoulder were markedly swollen. The left leg was held in flexion. There was loss of sensation over the left leg. Kernig's sign was more marked. July 1, the urticarial rash was much less evident during the last twenty-four hours. There was no retraction of the head. The patient died at 7 a. m. The temperature was constantly elevated during the three days in the hospital, ranging between 104 and 105 F. Necropsy was not obtained. The clinical diagnosis was acute lobar pneumonia, thrombosis of the cavernous sinuses, pneumococcus meningitis and fibrinous pleurisy. The eye signs, left, lasted five and one-half days, right, three and one-half days.

Etiology—This was not determined. The ears, throat and face showed no possible focus. The presence of a nasal discharge would point to the possibility of a sinus infection.

CASE 11—History—A private, Q. M. C., aged 21 years, admitted to the Base Hospital, Camp Grant, Ill., at 9:30 p. m., Sept. 7, 1918, complaining of headache and a boil on the nose, gave a negative history except that his mother had died of tuberculosis four years previously. The present illness had begun four days before admission with a boil on the bridge of the nose, which was incised at a regimental infirmary. For the last three days he had severe headache, which had kept him awake every night. On the day of admission he was nauseated. There was no vomiting. He felt chilly but he had no actual chill. The temperature at 4 p. m. is said to have been 104 F.

Physical Examination—On admission the temperature was 98.6 F, the pulse, 88. The patient appeared to be suffering with intense headache, but felt perfectly able to walk to the ward from the receiving office. General examination was entirely negative. The Kernig sign was negative. There was no rigidity of the neck. The knee kicks were equal and active. The eyes were normal in appearance, the conjunctivae were clear, the pupils were equal and reacted. The nose, ears, throat, teeth and sinuses were clear. The only positive finding was a furuncle on the bridge of the nose about 1 cm. in diameter. This had been incised and was draining bloody, creamy pus. A culture from this pus revealed *Staphylococcus albus*.

Course in Hospital—The patient was put to bed at 10 p. m. and given acetylsalicylic acid and codein for the pain. He vomited twice between midnight and 3 a. m. By 3:30 a. m., the temperature had gradually risen from 98.6 to 101.8 F. and the right eye was noticeably bulging and the lids slightly puffy. At 4 a. m. marked exophthalmos had developed on the right side with

edema of the lids. The conjunctiva was injected. The left eye was normal. The patient was quiet and rational but complained of intense headache. A diagnosis of thrombosis of the right cavernous sinus was made. At 7:30 a. m. the temperature was 102° F., the patient was semidelirious. Right exophthalmos increased; there was loss of vision in the right eye. The left eye was normal. Blood count revealed white blood cells, 19,500, polymorphonuclears, 80 per cent., eosinophils, 2 per cent., small mononuclears, 12 per cent., large mononuclears, 4 per cent., transitionals, 2 per cent. Blood culture revealed *Staphylococcus albus*. At 9 a. m., the patient was comatose. The left pupil was of pinpoint size, there was chemosis of the conjunctiva, the cornea was hazy. Edema of the right eyelid was increasing. Edema was present at the angle of the jaw and over the tip of the mastoid on the right side. Kernig's sign was positive; the neck was stiff. Knee kicks and Babinski's sign were negative. At 10:30 a. m. there was beginning edema of the left eyelids. Haziness of the media on the right prevents satisfactory examination of the fundi. On the left, the vessels were engorged, there was no choked disk. At 10:30 p. m. respirations were stertorous. Paralysis of the right arm and leg developed. Knee kicks were ++ and Babinski's sign was positive on the right. The temperature was 105.8° F. (axilla). Exophthalmos had developed on the left. There was extreme edema on the right extending over the forehead and down the right cheek to the angle of the jaw. The pulse gradually became weaker and respirations became more labored and irregular until death occurred at 6 p. m., twenty-one hours after the patient walked into the hospital. The temperature and pulse gradually rose from 98.6° F., and 88, respectively, on admission to 106° F., and 175, respectively, shortly before death. The clinical diagnosis was furuncle on the nose, septic thrombosis of the cavernous sinuses, septic meningitis, and right hemiplegia.

Necropsy—This revealed thrombosis of both cavernous sinuses and both superior petrosal sinuses; the clot was liquefying and semipurulent. There were edema and infiltration of the tissues of the right orbit, general septicemia with embolic foci in the viscera, localized basilar septic meningitis and a furuncle on the bridge of the nose. The paranasal sinuses, middle ears and mastoids, were clear. Cultures from the blood, cerebrospinal fluid and cavernous sinuses demonstrated *Staphylococcus albus*.

Comment—This case was remarkably fulminating in type. Death occurred twenty-one hours after admission, at which time the physical examination was entirely negative, and fifteen hours after the first appearance of eye signs on the right. The path of infection was along the angular vein, ophthalmic vein and cavernous sinus. Seven hours after the appearance of eye signs on the right, similar signs became evident on the left. There was early evidence of meningeal involvement, with the development of a right sided hemiplegia. The right fundus was never satisfactorily examined, but the left was examined repeatedly and showed engorgement of the veins but never a characteristic choked disk and no retinal hemorrhages.

CASE 12—History⁵—A private, Medical Department, U. S. Army, aged 25 was admitted to Evacuation Hospital No. 30, A. E. F., Mayen, Germany, about Feb. 23, 1919. The personal history was negative. There was no history of sore throat or trouble with the nose or ears. The present illness had begun

5 The field card of the following case is not available, and for this reason the data are given from memory and are therefore far from complete.

when routine throat cultures were taken on the personnel of the hospital unit and the patient was among those who showed a positive culture of *B diphtheriae*, though he gave no history of ever having had the disease. He was admitted to the isolation ward.

Physical Examination—On admission this was negative except for hypertrophied tonsils. The ears, nose and sinuses were normal.

Course in the Hospital—The throat cultures continued to be positive for *B diphtheriae* in spite of several injections of antitoxin and local treatment of the pharynx and tonsils. After the patient had remained in the isolation ward for more than a month removal of the tonsils was determined on.

Operation—March 27, 1919, tonsillectomy was performed under local anesthesia (swabbing with 10 per cent cocaine and injection of 1 per cent procaine containing a few drops of adrenalin). Both tonsils were easily and cleanly removed by dissection down to the base where a Tyding's snare was used. They were not adherent and there was little bleeding. After the operation was completed the tonsillar fossae were swabbed with compound tincture of benzoin. Cultures from each tonsil gave an abundant growth of *B diphtheriae*.

Subsequent Course—The postoperative course was uneventful until March 30, 1919, three days after the operation, when the patient began to complain of frontal headache and developed a temperature of 101 F. On April 2, six days after operation, the classical signs of cavernous sinus thrombosis were evident appearing first on the right side and two days later the patient died in coma. There were never any signs of local infection in the throat and no enlargement of the cervical glands. On April 2 examination of the fundi revealed a choked disk on the right side.

Necropsy—This revealed thrombosis of both cavernous sinuses and basilar meningitis. The jugular veins were not thrombosed. The paranasal sinuses, middle ears and mastoids were normal. Result of cultures at necropsy are not known except that the infecting organism was not the diphtheria bacillus.

Comment—A vein or veins draining the right tonsillar fossa must have become thrombosed, and the infection must have spread from this point to the pterygoid plexus and thence to the cavernous sinus. This unfortunate case presents a rare complication following tonsillectomy, and we have been unable to find a similar one in the literature. Septic thrombosis of the cavernous sinus has, however, been reported as a complication of a peritonsillar abscess.

HISTORICAL

Cavernous sinus thrombosis was first observed at necropsy by Duncan⁶ in 1821. The first clinical report was made by Vigla⁷ in 1839. Other early reports were by de Castelnau and Ducrest⁸ in 1846, by von Pitha⁹ in 1859, and von Cohn⁹ in 1860. In 1868, Herman Knapp¹⁰

6 Duncan, A., Jr. Contributions to Morbid Anatomy. Edinburgh M. & S. J. 17:334, 1821.

7 Vigla, E. N. De la morse ague chez l'homme, Theses de l'ecole de medecine 17:75, 1839.

8 De Castelnau, H., and Ducrest, J. F. Recherche sur les absces multiples, Paris 1846, p. 138.

9 Referred to by Knapp, Herman. Affection des Sehorgans bei Thrombose der Hirnsinus. Arch. f. Ophth. 14:220, 1868.

10 Knapp, Herman. Arch. f. Ophth. 14:220, 1868.

reported a case and called attention to the symptomatology of this condition. This is one of the best papers we have found in the literature. Knapp brings out very clearly the points of differential diagnosis between cavernous sinus thrombosis, orbital abscess, and other inflammatory conditions that cause exophthalmos.

The first operation on the cavernous sinus was performed by Dwight,¹ of Boston, in 1900. It was somewhat similar to Krause's operation for resection of the gasserian ganglion. The sinus was incised, a clot removed, and a cigaret drain inserted for drainage. The patient succumbed, however, within a few hours. One month later, Hartley,¹¹ of New York, performed a similar and successful operation, removing from one cavernous sinus a small round-cell sarcoma which was obstructing its lumen. The patient lived for several months, but eventually died of metastases. The work of Hartley showed that the sinus could be successfully operated on, and soon several methods were devised. The different types of operation will be described later.

ANATOMY

In the adult¹² the cavernous is a paired sinus which extends along the body of the sphenoid bone from the sphenoidal fissure to the apex of the petrous portion of the temporal bone. It measures about 2 cm. in length and about 1 cm. in diameter, but is of very irregular form. It is almost quadrilateral on cross section. The lumen is greatly reduced in size (1) by numerous trabeculae which traverse it and divide it into triangular spaces, and from which fringelike projections hang freely into the blood current, resembling on cross section the corpus cavernosum penis, whence its name, and (2), by the fact that the internal carotid artery, the carotid sympathetic plexus, and the abducens nerve transverse it. Embedded in its outer wall are these cranial nerves arranged in the order named from above downward: the oculomotor, the trochlear, and the ophthalmic and the maxillary divisions of the trigeminus.¹³

The cavernous sinus receives the ophthalmic veins (or vein), veins from the neighboring portions of the dura mater, from the sphenoidal

11 Reported by Knapp, H. A Case of Traumatic, at First Doubtful, Orbital Sarcoma, Followed by Aseptic Thrombosis of the Cavernous Sinus, *Arch Ophth* 29 463, 1900.

12 In the child the cavernous sinus is represented by a venous plexus in the dura mater, which by fusion is converted into the sinus of the adult. In old age, the trabeculae diminish and the cavity is less broken up. Quain *Anatomy*, New York, Longmans, Greene & Co. 2 524.

13 Piersol *Anatomy*, Ed 1, p. 872, Philadelphia: J. B. Lippincott Company.

sinus,¹⁴ from the pituitary body through the intercavernous sinuses, the sphenoparietal sinus, and sometimes it receives the middle cerebral vein. Posteriorly, it terminates in the inferior and superior petrosal sinuses, which empty into the jugular bulb and sigmoid sinuses, respectively. Veins pass thus from its undersurface (1) through the foramen ovale with the mandibular division of the trigeminal nerve to communicate with the pterygoid plexus, (2) through the fibrous tissue which closes the foramen lacerum medium to communicate with the pharyngeal or the pterygoid plexus, (3) through the foramen of Vesalius, likewise leading to the pterygoid plexus, and (4), occasionally, through the foramen rotundum with the maxillary division of the trigeminus. Also a close network of veins, the carotid plexus, extends downward along the carotid artery through the carotid canal, and eventually empties into the jugular vein.

The cavernous sinuses are connected by the anterior and posterior intercavernous sinuses, the one passing in front of, and the other behind, the pituitary body. Together they form the circular sinus.

Anteriorly and superiorly, the cavernous sinus is in close relation to the optic nerve and chiasm, laterally, to the gasserian ganglion, and internally, to the sphenoidal sinus¹⁵ and the pituitary body.

There is much difference of opinion about the order of frequency, but a study of the literature suggests that the areas from which infection may lead to thrombosis of the cavernous sinus and the venous paths to the sinus, may be thus classified¹⁶

1 *Ears and Mastoid*—The sigmoid sinus and jugular bulb are connected with the cavernous sinus through the superior and inferior petrosal sinuses, respectively. These sinuses also connect the various smaller veins of the external, middle, and inner ear, and the mastoid with the cavernous sinus.

2 *Face*—The facial vein is connected with the cavernous sinus by many anastomoses. It anastomoses with the angular vein, the supra-orbital and infra-orbital veins, the superior and inferior ophthalmic veins, the nasal veins, the facial communicating vein, and the pterygoid plexus, all of which either directly or indirectly communicate with the cavernous sinus.

14 Thomson, St Clair. Causes and Symptoms of Thrombosis of the Cavernous Sinus, *Ophth Rev* 27 294, 1908.

15 Sometimes the lateral or superior wall of the sphenoidal sinus is no thicker than writing paper, and, rarely, part of it is absent. Thus, in such cases, the cavity of the sphenoidal sinus is dangerously close to that of the cavernous sinus. Thompson, St Clair. Cerebral and Ophthalmic Complications of Sphenoidal Sinusitis: a Contribution on Two Cases with Autopsies, *Brit M J* 2 768, 1906.

16 Footnotes 1, 14 and 22.

3 *Orbit and Eyelids*—The ophthalmic vein drains the eyeball and through the angular vein the upper lid, and the palpebral branches of the facial vein drain the lower lid. The ophthalmic veins empty directly into the cavernous sinus. The palpebral veins communicate with both the angular and temporal veins.

4 *Nose and Accessory Nasal Sinuses*—The angular vein, the nasal veins, the anterior and posterior ethmoidal veins, and some of the sphenoidal veins empty into the superior ophthalmic vein and thence into the cavernous sinus. Veins from the sphenoidal sinus may also empty directly into the cavernous sinus.

5 *Mouth and Pharynx* (including the teeth and tonsils)—Various veins of this region empty directly or indirectly into the pterygoid plexus, which is connected with the cavernous sinus through the vein of Vesalius and veins through the foramen ovale and the foramen lacerum medium.

6 *Neck and Scalp*—The veins of these regions are connected with the cavernous sinus indirectly through the various veins of the diploe—the emissary vessels, and the occipital and posterior auricular veins.

ETIOLOGY

The three most common causes of a thrombosis of the cavernous sinus are marasmus, trauma and infection. Marasmic thrombosis usually occurs in association with debilitating conditions at the extremes of life. The cavernous sinus in this condition is always involved after the longitudinal or lateral sinuses, it is never primarily involved.¹⁷

The cavernous sinus may become thrombosed as the result of an injury to the skull. When it does it is more often associated with a fracture of the base. There are a few cases reported in which thrombosis has followed a direct injury to the sinus, both from wounds through the orbit and, accidentally, during operations on the gasserian ganglion.¹⁸

Septic thrombosis is by far the most common form. It is nearly always secondary to a thrombophlebitis of some of the afferent or efferent veins. But it may be primary in the cavernous sinus, due to

17 Macewen, W. *Pyogenic Infective Diseases of the Brain and Spinal Cord*, Glasgow, 1893, p. 245.

18 Cushing, Harvey (The Surgical Aspects of Major Neuralgia of the Trigeminal Nerve, *J. A. M. A.* **44** 920 (March 25) 1905) reported a case in which thrombosis of the cavernous sinus followed an injury to the sinus during an operation for resection of the gasserian ganglion, and which was not septic. The following symptoms appeared one month after the operation, suddenly, without pain and without the patient's knowledge: protrusion of the eyeball, rapidly forming edema of the eyelids, early retinal hemorrhage, and, later, blurred vision and opaque structures.

direct extension from a basilar meningitis, abscess of the postorbital space, a suppurative sphenoiditis, or suppuration of the petrous portion of the temporal bone. The bacteria most often reported are *Staphylococcus albus* and *Staphylococcus aureus*, *Streptococcus pyogenes*, the pneumococcus and *Diplococcus intracellularis*¹⁹

PATHOLOGY

Marasmic thrombi are sterile. As a rule the thrombus is also sterile in the traumatic and operative cases. Septic thrombi, as elsewhere, begin with a phlebitis and the usual phenomena of thrombosis follow. At first, the thrombus is red and friable. It is adherent to the walls and usually completely fills the lumen. It may become purulent. The walls of the sinus are thickened and lusterless and often perforated. Usually there is involvement of both cavernous sinuses and of other dural sinuses.²⁰ Often there is a purulent meningitis, usually basilar. Other complications may be meningeal hemorrhages, a serous meningitis of Quincke, brain abscess and emboli to the lungs and various parts of the body, with infarction of the lungs, liver, spleen or kidneys. Usually, there is more or less infection of the neighboring vessels and nerves. Frequently there is necrosis of the sphenoid and petrous portion of the temporal bone.

SYMPTOMS

The symptoms of cavernous sinus thrombosis may be divided into three groups (1), those due to venous obstruction, (2), those due to involvement of the neighboring nerves, and (3) those due to general sepsis. Those of the first two groups are the most important and of most diagnostic value. Those of the third group are usually dependent on an associated septicemia.

The symptoms of venous obstruction are exophthalmos, edema of the retina and edema of the eyelids and bridge of nose. They are due to intraorbital venous congestion and distention of the tissues behind the eyeball. Usually both eyes are involved, but one before the other, the second eye, as a rule, within forty-eight hours after the first. The symptoms may almost disappear in one eye while developing in the other, and their degree may vary several times during the course of the illness. Associated with the retinal edema one usually sees a dilatation and tortuosity of the retinal veins, retinal

19 Bacteriologic findings are frequently not included in the reports of cases, and it is difficult to determine the percentages from a small number of cases.

20 In more than half of the cases, both cavernous sinuses are involved (Dwight and Germain, Footnote 1).

hemorrhages, and, sometimes,²¹ a slightly choked disk. Clouding of the media and opacity of the cornea occur within a few hours after the onset of the eye symptoms, and therefore frequently the fundus cannot be seen. Edema of the upper eyelid may be so great as completely to close the eye. When the pterygoid plexus is thrombosed, there may be edema of the pharynx and tonsil on the same side, of the skin over the mastoid and neck, when the lateral sinus and jugular vein become thrombosed, and of the face, when the facial vein is likewise involved (Fig 3).

The cranial nerve symptoms are ptosis, dilatation of the pupil, restriction of the movements of the eyeball, loss of vision, pain in the region of the head supplied by the ophthalmic division of the trigeminal nerve and very rarely trismus. Ptosis is nearly always due to paralysis of the oculomotor nerve, but the closing of the eye may be due entirely to an extreme edema of the upper lid. Dilatation of the pupil may be due to a paralysis of the oculomotor or stimulation of the sympathetic plexus. This varies somewhat, probably due to changes in pressure or to the inflammatory involvement of these nerves. Early in the illness, the movements of the eyeball are restricted and soon the eye is almost or completely fixed. This is due to paralysis of the oculomotor, trochlear and abducens nerves. Pain in the eyeball and supra-orbital headache are frequently early symptoms and may be quite severe. The pain is more general and increased in severity when the meninges are involved. Trismus is a rare symptom and is, probably, due to irritation of the mandibular division of the trigeminal nerve. It was observed once by Otto²² and once by ourselves. Loss of vision is usually present, but vision may be retained even in severe cases as was illustrated by Case 8.

The symptoms of sepsis are septic temperature, rapid, small and thready pulse, and chills and sweats. The temperature usually ranges from 101 to 106 F, with marked depressions. The chills occur early, toward the end they may become frequent and are followed by profuse sweats. The patient may also suffer from vomiting, delirium and coma.

21 Stoker, F. *Arch f Augenh* **44** 105-146 (supplement number) 1901. When the cavernous sinus and ophthalmic veins are occluded a considerable amount of blood from the central retinal vein may escape through its anastomoses with other veins, and if the quantity of blood which enters through the central artery is reduced by the great increase of intraorbital pressure, it can be understood how this small quantity of blood may escape without inducing a choked disk.

22 Otto, K. (*Zur Kasuistik der Thrombose der Sinus cavernosi nicht otitischen Ursprungs* *Deutsch Ztschr f Chir* **110** 176, 1911) thinks it was probably due in his case to thrombosis of the pterygoid plexus.

Often there are symptoms of meningitis, of pulmonary embolism,²³ of infarction of spleen, kidneys or liver, and of septic emboli in various parts of the body

Sometimes the symptoms of thrombosis are more or less masked by those of the primary focus, especially when the infection begins in the orbit. Even when the progress of the disease is very rapid, as in Case 11, in which death occurred fifteen hours after the onset of symptoms, there may be marked edema of the lids, exophthalmos and other classical symptoms of a cavernous sinus thrombosis

Laboratory studies on the blood and spinal fluid are of value in reaching a diagnosis. The leukocyte count is usually very high—41,000 in Case 2, 32,000 in Case 3, 20,000 in Case 7, 23,000 in Case 8, 18,000 in Case 9, 23,500 in Case 10, and 19,500 in Case 11. In two cases of our series, however, there was a low leukocyte count—6,300 in Case 5 and 15,000 in Case 6, a child 4 years of age. In Case 8 of our series, the lumbar puncture on the thirteenth day of the illness revealed a clear fluid with a cell count of one mononuclear per cubic millimeter. The fatal cases, however, usually show a cloudy fluid and a high cell count. Blood cultures are positive in the majority of cases

DIAGNOSIS²⁴

A history of chills and severe headache, a septic temperature and an exophthalmos that always begins on one side, but usually involves the opposite eye within twenty-four or forty-eight hours, are pathognomonic of thrombosis of the cavernous sinus. The temperature in cavernous sinus thrombosis, as in thrombosis of the sigmoid sinus or jugular bulb, is usually septic in character, in three of our cases, however, the fever was of the continuous type (Cases 3, 5 and 10)

The primary infection on the face may be insignificant. In Case 11, the primary focus was a small furuncle on the bridge of the nose of four days' duration. In Case 9, the primary focus was an infected hair follicle in the vestibule of the nose of three days' duration

When only one eye is involved the following conditions may at times simulate a septic thrombosis of the cavernous sinus: erysipelas, cellulitis of the orbit secondary to an infection of the accessory nasal sinuses (Fig 10), tumors of the orbit and arteriovenous fistula of the internal carotid artery (Fig 11)

23 Hampton H H and Wharton L R. Venous Thrombosis, Pulmonary Infarction and Embolism Following Gynecological Operations, *Bull Johns Hopkins Hosp* 31:95 (April) 1920

24 Posey, W C, and Spiller W G. Eye and Nervous System, Philadelphia, J B Lippincott Company, 1906, p 871 also Footnote 17

Orbital cellulitis, tenonitis and thrombophlebitis of the ophthalmic veins may be differentiated at times with difficulty from a cavernous sinus thrombosis. In the first two conditions there is often a history of previous eye trouble and more signs of inflammation in the eye than are usually found in a cavernous sinus thrombosis, also the signs of venous obstruction are less marked. The headache is usually less severe, and there are no signs or symptoms of a general septicemia or of meningeal involvement.

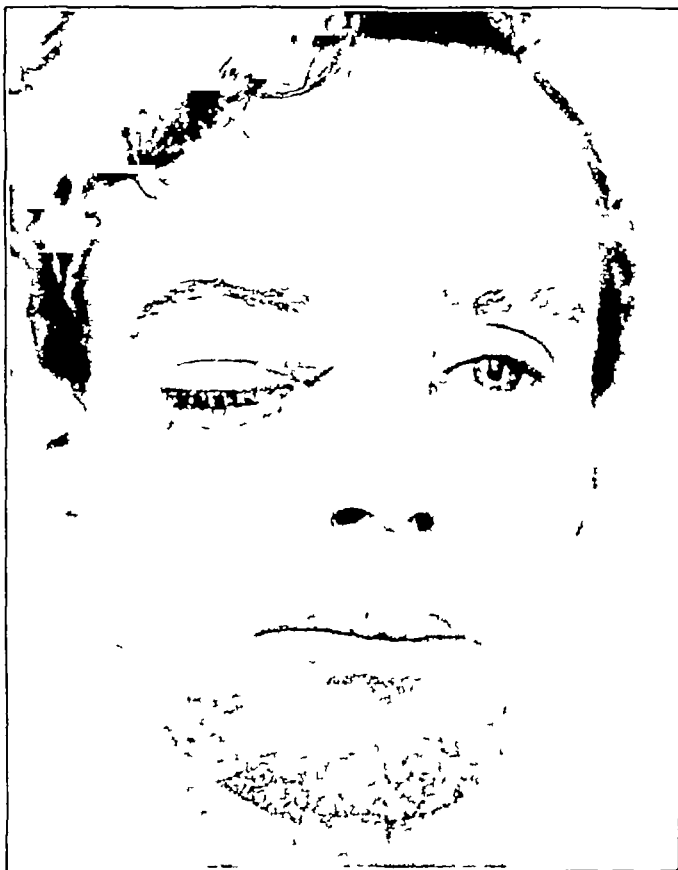


Fig 10—A case of orbital cellulitis secondary to an ethmoidal infection. The swelling and exophthalmos subsided promptly and permanently following an intranasal ethmoid operation.

Erysipelas often begins on the face or around a recent mastoid wound. It may, however, begin on the upper lid and for a few hours closely resemble a cavernous sinus thrombosis. The latter condition should always be considered as a possible complication of erysipelas. There are several cases in the literature in which the cavernous sinus became infected from a primary facial erysipelas.

A new growth in the orbit or sella turcica and an arteriovenous fistula of the internal carotid artery (a not uncommon complication of a fracture of the base of the skull) will scarcely be confused with a septic cavernous sinus thrombosis. The symptoms of a growth in this locality are gradual in onset, and there are no signs of a general infection. In the latter condition, there is often a history of injury and a bruit can usually be heard at some point over the forehead.

Thrombosis of the superior longitudinal sinus is usually a terminal complication in malnutrition or cachexia and is characterized by a cyanosis of the face, dilatation of the veins of the scalp and epistaxis.

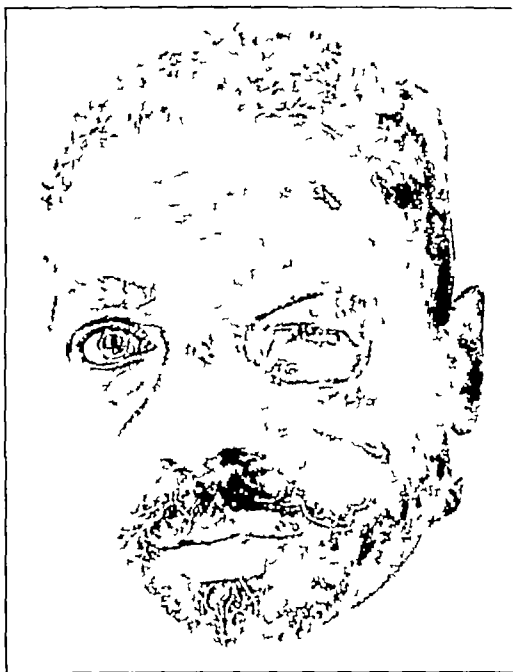


Fig. 11—A case of arteriovenous aneurysm of the internal carotid and the cavernous sinus, following a fracture of the base of the skull. Edema of the lids and exophthalmos developed gradually after the injury. A loud bruit could be heard above the inner end of the orbital ridge.

TREATMENT

All agree that the focus of infection if found should be as thoroughly removed as possible. But there is much difference of opinion over the best method of treating the thrombosed sinus itself. Many prefer to treat the symptoms as they arise. Others advocate prompt and radical operations on the cavernous sinus, as only 7 per cent of these patients recover without operation.¹ The number of patients that have recovered as a result of operation on the cavernous sinus, however, is less than 7 per cent.

Chief among the various operations proposed for treating the sinus are the temporal route of Dwight and Hartley,²⁵ the orbital route of Mosher,²⁶ the ethmoidal-sphenoidal route of Langworthy,²⁷ and Luc's²⁷ operation through the antrum on the opposite side. The temporal route of Dwight and Hartley is almost the same as far as the approach is concerned as Krause's operation for resection of the gas-serian ganglion, the difference being that the dura is incised. Dwight found that an incision in one sinus will drain both. This operation has been performed by Dwight, Hartley and Ballance²⁸. The one performed by Hartley was the only one that was successful. In Hartley's case the thrombosis was due to a small round-cell sarcoma and was not associated with infection.

The orbital route of Mosher requires removal of the eye, ligation of the ophthalmic artery, removal of the inner half of the orbital plate of the great wing of the sphenoid bone and elevation of the brain before the cavernous sinus is exposed. An incision is then made in the outer wall of the sinus and the thrombus is removed with a curet. Adair Dighton²¹ performed a very similar operation on one patient, but it was not successful. The ethmoidal-sphenoidal route of Langworthy is similar to the external operation for removal of the ethmoidal cells. In addition, the anterior and lateral walls of the sphenoid are removed and the cavernous sinus opened by means of a blunt curet. In the Luc operation the cavernous sinus is approached through the maxillary antrum and the sphenoidal sinus on the opposite side. He considers the oblique angle thus obtained as very important. Robineau²⁷ employs temporary resection of the malar bone with trephination of the sphenoid.

Bircher³⁰ has reported a case in which he opened and drained the cavernous sinus by resecting the petrous portion of the temporal

25 Footnotes 1 and 11

26 Mosher, H. P. Orbital Approach to the Cavernous Sinus, *Laryngoscope* **24** 709, 1914

27 Langworthy, H. G. Anatomic Relations of the Cavernous Sinus to Other Structures with Consideration of Various Pathologic Processes by Which It May Become Involved, *Ann Otol, Rhinol & Laryngol* **25** 554 (Sept.) 1916

28 Ballance, C. A., and Hobhouse, N. A Case of Septic Thrombosis of the Left Sigmoid, Left Cavernous, and Left Inferior Petrosal Sinuses with a Suggestion for Treatment in Future Cases, *Ninth Intern Otol Congress*, 1912, p. 308

29 Dighton removed most of the superior wall of the orbit from one inch in front of the sphenoid fissure backward, elevated the frontal lobe and curetted the cavernous sinus. Patient died. Dighton, A. Cavernous Sinus Thrombosis of Nasal Origin, *Med Press & Circ* **96** 450, 1913

30 Bircher, H. Phlebitis des Sinus transversus, petrosus inferior und cavernosus. Eröffnung und Desinfektion nach Entfernung der Felsenbeinpyramide. Heilung. *Centralbl f Chir* **22** 483, 1893

bone In this case there was an extensive suppuration of the mastoid and of the pyramid of the temporal bone, and a thrombosis of the jugular bulb and the inferior petrosal sinus This accounts for the method of approach employed The patient made a perfect recovery with the exception of a permanent paralysis of the facial nerve The only eye symptoms in this case were those due to paralysis of the orbital nerves, and we do not believe that the diagnosis of cavernous sinus thrombosis was entirely justifiable But if the diagnosis is accepted, this is the only report we have been able to find in the literature of a successful operation on the cavernous sinus for septic thrombosis

CONCLUSION

Operation on the cavernous sinus was not attempted in any of our cases, and the percentage of recovery was 83.3 When operative treatment is contemplated it would seem that the location of the focus of infection should be a determining factor in choosing the route of approach For instance, if the focus is in the orbit the route of Mosher might be employed, but if it is in the ethmoids or sphenoid the route of Langsworthy might be used The failure of surgical intervention is undoubtedly due to the fact that a basilar meningitis and a thrombosis of the neighboring venous sinuses occur, as a rule, early in the course of the disease A lumbar puncture should always be performed, for the patient may manifest the usual symptoms and signs of meningitis and yet have a clear spinal fluid If examination of the spinal fluid reveals the presence of a septic meningitis, mere drainage of the cavernous sinus is manifestly inadequate If, on the other hand, the spinal fluid is clear, the patient has a chance for recovery without operation

SUMMARY OF FINDINGS

Infecting Organisms—Total cases, 12 *Staphylococcus aureus* 5, pneumococcus, 3, *Staphylococcus albus*, 1, streptococcus, 1, and undetermined, 2

First Sinus Involved—Right involved first, 7, left involved first, 5, and unilateral involvement, 1

Result—Death, 11, necropsy, 6, no necropsy, 5, and recovery, 1

Focus of Infection—Paranasal sinuses, 3 (Cases 3, 5 and 8), alveolar infection, 3 (Cases 1, 4 and 6), facial infection, 2 (Cases 9 and 11), pharynx (after tonsillectomy), 1 (Case 12), orbital abscess (injury), 1 (Case 2), not determined (probably paranasal sinuses), 2 (Cases 7 and 10), and ears and mastoids, 0

Complications—Meningitis, 10 (all except Cases 6 and 8), pneumonia, 4 (Cases 5, 7, 8 and 10), nephritis (acute), 3 (Cases 7, 8 and 9), hemiplegia, 2 (Cases 2 and 11), sweating (unilateral), 1 (Case 3), bones and joints, 1 (Case 8), and no apparent complication, 1 (Case 6)

Duration of Disease (Determined by eye signs) —Longest, 35 days, shortest, 15 hours, average, 9 days, average (omitting long case), 6 days, average (omitting short case), 7 days, case of recovery, 3 weeks of eye signs

Blood Culture—Positive, 5, *Staphylococcus aureus*, 2 (Cases 8 and 9), *Staphylococcus albus*, 1 (Case 11), *Streptococcus pyogenes*, 1 (Case 5), and pneumococcus, 1 (Case 7)

Negative Two (one of these also negative at necropsy), Cases 1 and 4

Not taken Four (Cases 2, 3, 6 and 10)

Result not known One (Case 12)

Spinal Fluid Culture or Smear—Positive, 6 (one at necropsy only) *Staphylococcus aureus* 3 (Cases 2, 3 and 9), pneumococcus, 2 (Cases 1 and 10), and *Staphylococcus albus* 1 (Case 11)

Negative One (Case 8)

No Examination of Spinal Fluid Four (Cases 4, 5, 6 and 7)

Result Not Known One (Case 12)

Prodromal Symptoms—Case 1, toothache for 5 weeks, Case 2, headache for two months, acute onset few hours, Case 3, 1 week after injury, acute onset, Case 4, toothache followed by facial infection for 3 months, Case 5, cold in head for 5 days, Case 6, toothache for 3 days, Case 7, septic temperature for 23 days, Case 8, sudden onset two days after swimming, Case 9, infection of anterior nares for 3 days, Case 10, measles for 2 weeks, Case 11, boil on nose for 4 days, severe headaches for 3 days, and Case 12, headaches and fever for 3 days, which developed 3 days after tonsillectomy

DUODENAL DIVERTICULA, WITH REPORT OF A CASE

E C MOORE, M D

LOS ANGELES

Diverticula have occasionally been found in various parts of the alimentary tract. According to Busch¹, the rarest diverticula are those of the stomach, then follow those of the duodenum, pharynx, esophagus, ileum and colon. All the early cases were discovered during postmortem examinations, they were not suspected during life and were in no way considered responsible for the death of the patient. The records show they are more frequently found in the bodies of people past middle life. Wilkie² states that 83 per cent are found in people over 50 years of age. They were considered rare then, as they are now. However, it should be noted that during the last five years, more and more cases have been reported, and it seems probable that they are of more frequent occurrence than they were believed to be at one time.

Busch¹ found that in 1710 Chomel³ had reported a case, before the Academy in Paris, of a woman, 80 years old, who had a duodenal pocket in which there were twenty-two stones. Chomel³ mentions that two hours after meals this woman always experienced pain in the exact spot where this pocket lay. However, most authors give Morgagni⁴ credit for having reported the first typical duodenal diverticulum in 1761.

ORIGIN OF DUODENAL DIVERTICULA

Two theories of the origin of duodenal diverticula have been advanced—the congenital and the acquired. Some investigators believe that the majority of cases are congenital, but that in a few instances the condition may have been acquired. Most authors subdivide congenital and acquired into true and false—a true diverticulum being one that contains all layers of a normal bowel, i. e., mucosa, submucosa, muscularis and peritoneum, and false diverticula those in which the muscularis is lacking.

It has not been possible to obtain the original manuscripts of the earlier investigators. For this reason, it has seemed best to enumerate

1 Busch, G. Beitrag zur Untersuchung der Duodenaldivertikel, Virchow Arch f path Anat **206** 121-141, 1911

2 Wilkie, D. P. D. Duodenal Diverticula and Duplication of the Duodenal Wall. Edinburgh M J **11** 219-229, 1913

3 Chomel. Histoire de l'Acad. Royale, Paris 1710, quoted by Busch (Footnote 1)

4 Morgagni. De sedibus et causis morborum Epist. 34, Par. 17, quoted by Busch (Footnote 1)

ate briefly the principal hypotheses regarding the etiology of diverticula, accepting Busch¹ as authority for these. Fabricio asserts that pressure from scybala is the cause, while Morgagni⁴ is inclined to believe the origin is congenital, although he does not deny the scybalum theory. Meckel⁵ proved that many diverticula are remnants of the vitelline duct. Fleischmann⁶ is of the opinion that diverticula lying near the common bile duct are caused by a spreading of the muscle fibers, consequently they are acquired. His opinion is shared by Roth,⁷ Keith⁸ and Basset⁹. Busch¹ asserts this argument is founded on anatomic and physiologic misconceptions. Keith⁸ believes traction of the bile duct, together with general abdominal ptosis, can produce traction diverticula, while Roth⁷ is of the opinion that they are caused by traction from an atrophic pancreas. Busch¹ finds it hard to conceive how the bile duct could produce traction upon the walls of the duodenum. The fact that many an atrophic pancreas is found without the slightest trace of a diverticulum forces Busch¹ to the conclusion that this is a far-fetched and artificial argument.

Another theory is that pulsion diverticula arise from abnormal pressure from within, when the passage of intestinal contents is hindered. According to Keith⁸ this occurs when there is pressure upon the fourth part of the duodenum, or ptosis of the colon, which produces the same effect as pressure from corsets. Busch¹ does not agree with these views, principally because the contents of the duodenum are fluid, hence the pressure exerted upon it must be less than upon any other part of the intestinal tract. The influence of the corset can only be very slight, because diverticula of the duodenum have been found twice as frequently in men as in women.

As contrasted with the views of these investigators, Letulle,¹⁰ Gandy¹¹ and Marie¹² are of the opinion that diverticula of the duo-

5 Meckel. *Handb d path Anat* Leipzig, 1816, quoted by Busch¹ (Footnote 1)

6 Fleischmann. *Leichenöffnungen*, Erlangen, 1815, quoted by Busch¹ (Footnote 1)

7 Roth. *Ueber Divertikel am Duodenum*, Virchows Arch f path Anat **56** 197, 1872, quoted by Busch¹ (Footnote 1)

8 Keith, A. A Demonstration on Constriction and Occlusions of the Alimentary Tract of Congenital or Obscure Origin, *Brit M J* **1** 301, 1910, quoted by Busch¹ (Footnote 1)

9 Basset. Duodenal Diverticula, *Tr Chicago Path Soc* **7** 1907, quoted by Busch¹ (Footnote 1)

10 Letulle. Malformations duodénales diverticules perivateriens, *Bull Soc anat Paris*, 1898, quoted by Busch¹ (Footnote 1)

11 Gandy. Diverticule duodénal congénital, *Bull Soc anat Paris*, 1900, quoted by Busch¹ (Footnote 1)

12 Marie. Diverticules duodénaux perivateriens, *Bull Soc anat Paris*, 1899, quoted by Busch¹ (Footnote 1)

denum are congenital. The following are the principal reasons which induced Busch¹ to accept this theory.

1 The duodenum is the part of the intestinal canal which undergoes the most changes during fetal life, because the bile and pancreatic ducts are evolved from it.

2 Shaw's case, unquestionably congenital, in which diverticulum and at the same time occlusion of the duodenum were found in a new-born infant, proves that these diverticula are encountered in earliest childhood.

3 Duodenal diverticula are coexistent with other congenital diverticula.

4 Directly beneath the pylorus, pancreas accessorium (appendices pyloricae), or so-called duodenal culdesacs, which Meckel⁵ had previously recognized, were frequently found.

5 Lewis and Thyng¹³ observed that during the second fetal month in mammals there is found a rich epithelial growth along the entire course of the alimentary canal, especially in the duodenum and jejunum.

6 In most cases ulcers, tumors, stones, ascaris, scybala and scars are absent, also there are no changes in the pancreas, liver and intestine.

7 In the fetus the duodenum changes from a straight line to horseshoe shape. The objection that such diverticula are found in adults no longer has weight, because of Shaw's case.

8 Many diverticula are turned directly toward the head of the pancreas, resting therein as in a niche. Does it not seem absurd to believe that the posterior wall of the duodenum, which is the thickest and furthermore is reinforced by the pancreas, should be the very one to give way?

Busch¹ in his three cases found no stones, tumors, scars, adhesions or inflamed pathologic condition of neighboring organs, in fact, nothing which indicated that the diverticula were acquired. In his second and third cases there was a slight inflammation in the duodenum and diverticulum, which he believed proved nothing because in 90 per cent of the necropsies gastro-enteritis was found without causing any collapse of the intestinal wall. On the other hand, all the findings were in favor of the theory of congenital origin. Although Busch¹ does not deny that an acquired diverticulum is possible, he maintains that duodenal diverticula in general and his three cases in particular were congenital.

13 Lewis, F. T. and Thyng, F. W. The Regular Occurrence of Intestinal Diverticula in Embryos of the Pig, Rabbit and Man, *Am. J. Anat.* 7: 505-519, 1908.

Early observers uniformly coincide in the belief that diverticula of the duodenum do not produce symptoms. Bauer¹⁴ should be given credit for being the first to point out that in his two cases definite symptoms were associated with the diverticula of the duodenum.

Wilkie² reports three cases of diverticula of the duodenum, in two of which the diverticula were associated with grave disturbances in adjacent organs. In one of his cases, in a man, aged 58, calculi were found in the gallbladder, common bile duct and also in the cystic duct. In the second part of the duodenum, there was a curious condition of infolding of the duodenal wall and 2 inches below this there was a second similar infolding. About 1 inch above the papilla, there was an opening which admitted the thumb and which led into a sac filled with 15 c.c. of tenacious mucus. This large diverticulum was also associated with an accessory pancreas. This patient had been seized with abdominal pain fifteen hours before entering the hospital and died one hour after admission. His second case was that of a woman, aged 47, whose death was due to heart failure. Necropsy revealed an extreme degree of hepatic cirrhosis and a gallbladder containing four large mulberry-like stones. There was a large ulcer in the first part of the duodenum, on the posterosuperior wall, half an inch beyond the pylorus. In the second part of the duodenum, immediately to the outer side of the papilla of Vater, there was a diverticulum 1 inch in length, extending upward behind the duodenum. Wilkie² considers the first case a congenital diverticulum, and believes the diverticula in both cases offered strong presumptive evidence that there was some etiologic relationship between the diverticula and the biliary troubles.

Since the advent of the roentgen ray and the routine bismuth meal examination of all patients complaining of intestinal disturbances, our knowledge of the symptomatology of this condition has had its greatest impetus. By the fluoroscopic method it is now possible to see what is actually taking place. Thus several later investigators believe that diverticula of the duodenum are health disturbing factors at times. More and more proof to support this view is being assembled. The following are brief résumés of reported cases.

Forssell and Key¹⁵ report a case of false diverticulum of the pars descendens duodeni in a woman, aged 41, who for a number of years had suffered from gastric distress, resembling that caused by ulcer.

14 Bauer, T. Ueber das Duodenaldivertikel, *Wien klin Wchnschr* **25** 879-880, 1912.

15 Forssell G., and Key, E. Divertikel a pars descendens duodeni diagnoserad medels Roentgenundersokning och operativ aflagnadt, *Hygiea* **77** 63, 1915.

The authors assert that this case is probably the first in which a diverticulum of the duodenum has been removed surgically, having previously been diagnosed by the roentgen ray. This patient has been relieved of the former symptoms since the operation.

Case ¹⁶ states he has observed eight cases of real diverticulum of the duodenum, occurring in the pars inferior. One of these patients, a woman, aged 45, had had pain in the lower dorsal region for six years. A definite diverticulum of the duodenum in the pars inferior, measuring 2.5 by 5 cm., was demonstrated by roentgen-ray examination. Food was retained in this diverticulum a little longer than the time it took for the stomach to empty itself. At operation, a diverticulum was found 5 cm. above the duodenojejunal junction in the third part of the duodenum, extending upward, behind and into the substance of the head of the pancreas. The gallbladder was drained, the appendix removed and the incompetent ileocecal valve repaired, but nothing was done to the diverticulum because of its intimate connection with the pancreas and because of its proximity to the superior mesenteric vessels. Six months after this operation the patient was still free from the severe pain.

Some interesting questions arise in connection with this case. Was the chronic pancreatitis caused by the faulty drainage of a diverticulum of congenital origin, and if so, why have the symptoms disappeared without the removal of the diverticulum? Or is this an acquired diverticulum secondary to a pathologic condition of the gallbladder and pancreas?

Basch ¹⁷ reports a case of a diverticulum of the duodenum in a woman, aged 36, in whom the location of the diverticulum and the roentgenogram and operative findings were very similar to those reported by Forssell and Key ¹⁵. This patient had suffered for many years from symptoms suggestive of duodenal ulcer. At operation, the first and second portions of the duodenum were found to be congested and bound together by numerous fine adhesions. A large diverticulum, measuring about 3 by 4 cm., the base of which was about 3 cm. in diameter, was found at the angle between the second and third portions. The diverticulum was excised at its base, and after closing the resulting opening, a typical posterior gastro-enterostomy by suture was performed. At the time Basch wrote his article the patient showed a decided improvement in her digestion. Basch considers this case a congenital diverticulum of the duodenum.

16 Case, J. T. Roentgen Observations on the Duodenum with Special Reference to Lesions Beyond the First Portion, *Am J Roentgenol* **3** 314-326 (June) 1916.

17 Basch, S. Diverticulum of the Duodenum with a Report of a Case Diagnosed During Life and Successfully Operated on. *Am J M Sc* **153** 833-841 (June) 1917.

Ritchie and McWhorter¹⁸ report a case of diverticulum just below the pylorus on the lower side of the duodenum in a woman, aged 32. This diverticulum was 5 cm. in length and 3.5 cm. in diameter, egg-shaped, with a narrow isthmus that easily admitted the tip of a finger. A large duodenal ulcer was nearly opposite the opening of the diverticulum. The operation performed consisted of partially invaginating the wall of the sac by plication. The scar of the ulcer was invaginated with a few Lembert sutures and a typical short loop posterior gastroenterostomy was performed. In a letter from Dr. Ritchie dated June 1, 1920, he said that all symptoms referable to the stomach had disappeared. The woman asserted that she was perfectly well and looked it, having gained about 30 pounds. In this case the history shows that as far back as the patient could remember she had had similar periodic abdominal pains with nausea and vomiting, several times accompanied by jaundice. For the last two years, the symptoms had become more frequent and aggravated. The fact that the history dated from early childhood suggested to the authors the possibility of a congenital origin. However, the explanation which they consider fits their case best is that a spastic incisura as well as a relaxation of the duodenum with ptosis predisposed to the development of a diverticulum.

When Carman¹⁹ states that either true or false diverticula result occasionally from duodenal ulcer, true diverticula in less than 1 per cent. of the total number of ulcers, he certainly must be referring to ulcer diverticula only. It seems to me that Ritchie and McWhorter's case and the one that I am reporting are entirely different from those described by Carman¹⁹. In this connection it would seem appropriate to draw especial attention to Wilkie's² second conclusion, which expresses my views so perfectly that I quote it verbatim:

"In the first part of the duodenum three types of diverticula are met with, the congenital, the ulcer diverticulum, and the acquired wide-mouthed diverticulum of the duodenal vestibule."

Considerable confusion seems to have arisen from designating all of them simply as diverticula, whereas an ulcer diverticulum presents a totally different roentgenogram from that produced by a congenital diverticulum. Case¹⁶ points out this distinction in his article when he says: "One occasionally finds a sort of diverticulum associated with the scar of duodenal ulcer, or with pericholecystic adhesions, but these occur in the first portion of the duodenum."

18 Ritchie, H. P., and McWhorter, G. L. Duodenal Diverticula, with Report of a Case Associated with a Duodenal Ulcer, *Surg., Gynec. & Obst.* **25**: 485-489 (Nov.) 1917.

19 Carman, R. D. The Roentgenologic Diagnosis of Duodenal Ulcer, *Am. J. Roentgenol.* **3**: 252-256 (May) 1916.

Siegrist²⁰ reports a case of false acquired diverticulum of the duodenum in a man, aged 48. At the age of 23 this man experienced an abdominal traumatism which was followed by an epigastric hernia. A radical operation was performed upon him. Twenty-five years later during an exploratory laparotomy a diverticulum of the duodenum was found implanted on the second part of the segment of the intestine in the region of the ampulla of Vater and united by adhesions to the head of the pancreas. The diverticulum was removed and the patient recovered. The author is of the opinion that the diverticulum dated back to the traumatism.

REPORT OF AUTHOR'S CASE

History—A man, aged 58, complained of a dull, heavy, dragging pain in the abdomen, 1 inch to the right and 2 inches above the umbilicus, which came about three hours after eating, and which was worse in the afternoon. He found relief in lying down, but not from taking food. Occasionally he had a sour stomach, but this condition was not constant, and he secured relief by taking soda. The trouble dated back seven years, beginning with a distress immediately after eating. This had lasted about three weeks when it disappeared. Following this he was well for one year when he developed a bloody diarrhea with much mucus. This was diagnosed mucous colitis and treated but without improvement. While being treated for this trouble, he was suddenly seized one day while in the physician's office with severe agonizing pain in the epigastrium, so severe that hypodermics of morphin were required. The severe pain lasted about twenty hours. There was neither fever nor vomiting. Following this, the abdomen, and especially the epigastrium, was acutely tender for about two weeks, necessitating his remaining in bed. The condition was diagnosed appendicitis. From then up to the present time, the gastric symptoms had gradually increased in severity, but there had been no regularity in time of onset.

Physical Examination—The patient was a fairly well nourished man, with no general glandular enlargement. The mouth and teeth were in fair condition, the heart and lungs showed no pathologic condition. The blood pressure was 140, systolic, the temperature was 98.6 F, and the pulse 88. No tumor masses were felt in the abdomen, but there was a definite tender area in the upper abdomen just above and to the right of the umbilicus. No impulse was felt in the inguinal rings. Rectal examination revealed a small, soft prostate. The reflexes were normal. Urine examination disclosed specific gravity 1.020, acid, albumin, +, occasional red blood corpuscles and a few calcium oxalate crystals. The Wassermann test was negative. The stool was negative for blood.

Diagnosis—The roentgen-ray examination in this case was the determining factor in the diagnosis. Dr. Frances C. Turley, our roentgenologist made the following report, Nov. 13, 1916:

²⁰ Siegrist, H. Duodenal Diverticulum in Man of Forty-Eight. *Correspondenzschweiz Aerzte* 49:47 (Jan. 11) 1919, *abst. Inter. Abst. Surg.* 29:15 (July) 1919.

The esophagus is negative. The stomach has good tone. The peristaltic waves are deep and pass out rapidly on both curves to the pylorus. There are no gastric filling defects. The pylorus does not open at once, although there is no marked pylorospasm. After a few minutes' observation the pylorus opens, the bulb fills, but is somewhat irregular in outline, and is situated more posteriorly than is normally the case. There is no tenderness over the bulb on palpation. About ten minutes after ingestion, with the patient in the left right oblique position on the horizontal fluoroscope, a large diverticulum on the anterior surface of the second part of the duodenum is seen to fill out. If the patient is asked to locate the area of greatest distress he points each time to a point directly over the site of the diverticulum. At the four-hour observation

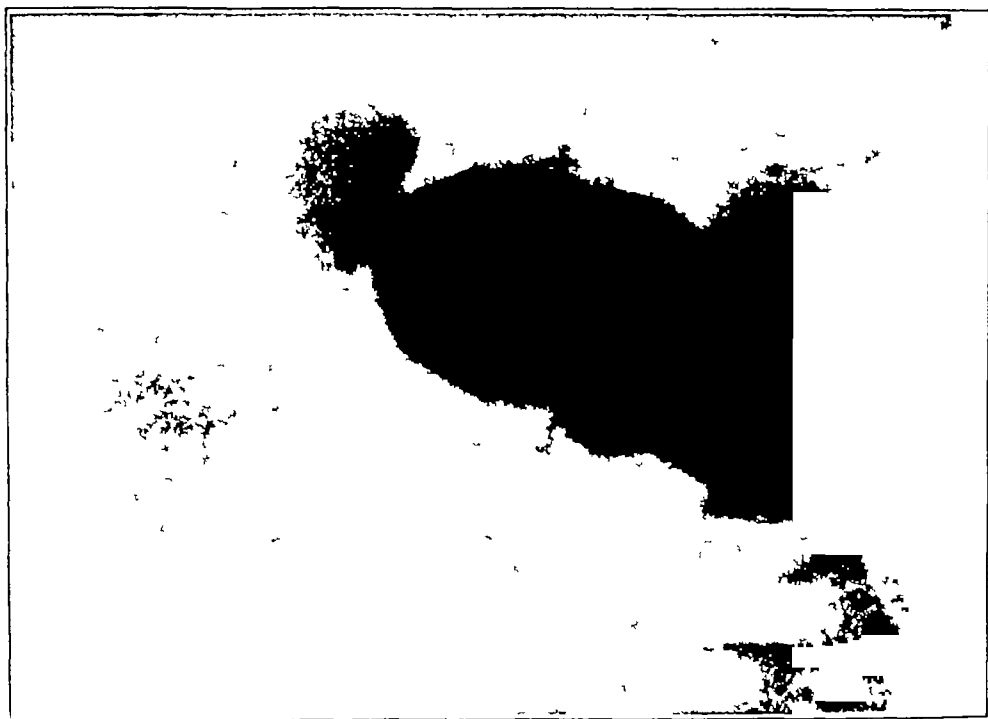


Fig 1—Condition, Nov 13, 1916 before operation. Diverticulum of the duodenum projecting from the anterior surface of the second portion of the duodenum.

the stomach is almost empty, the diverticulum is still distended. The head of the opaque column has almost reached the splenic flexure. The cecum is freely movable, the appendix is not visualized. At the twenty-four hour observation the cecum, ascending and transverse colon contain opaque contents, the descending colon is free from shadows, the sigmoid and ampulla are opaque. The appendix is visualized, is quite long and is irregularly filled. Summary: Stomach, negative, duodenum, bulb irregular in outline, second part shows a large diverticulum on the anterior aspect (Fig 1).

Operation—Nov 20, 1916, a right oblique supra-umbilical incision was made. When the duodenum was exposed a large diverticulum, 2.5 cm by 3.8 cm, was seen on the anterior wall of the lower end of the descending portion of the duodenum. The diverticulum was more or less flattened out over the anterior surface of the duodenum by thin weblike avascular adhesions. After

the diverticulum was dissected free, it filled out with gas like a toy gas balloon, being almost spherical and 6 cm in diameter. It had a small pedicle, the opening into the duodenum being about 1 cm in diameter. About 25 cm distal to the pyloric ring on the anterior surface of the duodenal wall was an old scar of a healed duodenal ulcer, not producing obstruction. The pedicle of the diverticulum was clamped and the diverticulum amputated. The stump was treated in a manner similar to that used in the case of an appendix stump. This, however, caused considerable stenosis of the duodenum and a posterior gastro-enterostomy was performed with the loop turned to the right instead of the left because of the position of the jejunum.

Pathologic Report (by Dr R. B. Hill)—*Gross Description* The specimen is an intestinal pouch, 25 cm by 25 cm by 15 cm in diameter. The surface is rather irregular and is covered by a smooth layer of peritoneum. The mucous membrane is smooth and velvety in appearance and the valvulae conniventes, while present, do not stand out prominently. The wall measures 25 mm with no irregular thickenings. Microscopically, sections show the mucous membrane to be made up of typical villi covered by a single layer of columnar epithelium, between which are characteristic crypts of Lieberkuhn. Scattered through the stroma are many eosinophils and occasional polyblasts. Two or three solid masses of lymphoid tissue are seen just above the submucous muscular layer. The muscularis mucosae is very much thickened and is infiltrated with occasional eosinophil cells. There is no true muscular layer, however occasional large irregular masses of bundles of muscle fibers are seen. The serous covering is somewhat thickened and has numerous eosinophils and occasional small round cells scattered through it. The blood vessels are quite large and seem to be distended. The diagnosis is true duodenal diverticulum showing a moderate degree of chronic inflammation.

COMMENT

On June 1, 1920, this patient called on us at our request in order that we might determine his present condition. He stated that he had been absolutely relieved of all the former gastric symptoms. A gastro-intestinal examination made by Dr. Turley on June 2, 1920, resulted in these findings:

The esophagus was negative. The filled stomach had good tone. Peristalsis began at once, the opaque meal passed the pylorus and gastro-enterostomy opening at once. The greater part passed the gastro-enterostomy opening. There was no tenderness over either opening. There was no hindrance to the passage of the opaque meal along the duodenum or jejunum. The gastric motility was about five hours. The ascending colon was one-half filled in five hours and was movable. The terminal ileum was movable from the colon and normal in appearance. The appendix was not seen (Fig. 2).

The interesting features of this case are

1. A large diverticulum was found on the anterior aspect of the second portion of the duodenum.

2. A scar of an old healed duodenal ulcer was present on the anterior wall of the first part.



Fig 2—Stomach and duodenum, June 1, 1920, showing bismuth passing through stoma and duodenum

3 All symptoms seemed referable to the diverticulum

4 The diverticulum was amputated, our case being the fourth on record in which this was done, so far as we have been able to determine

It would seem from our observations and from a study of the literature on this subject that ours was a case of congenital diverticulum. As a rule, persons having these congenital defects experience no untoward symptoms. However, occasionally symptoms do occur, probably caused by faulty drainage. Faulty drainage may produce irritation of the mucous membrane, and this may furnish a good field for bacterial growth, resulting in inflammatory changes which produce acute symptoms. Latarjet²¹ is of the opinion that it seems only safe to say that nearly all diverticula of the duodenum are of congenital origin and that mechanical or inflammatory factors cause the symptoms or direct attention to them.

21 Latarjet, A., and Murad, J. Les diverticules de l'intestin grêle, diverticule de Meckel excepté, *Lyon chir* **11** 425-460, 1914, abstracted

LATE RESULTS IN AUTOGENOUS INTERNAL BONE SPLINTING

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In the development of bone-grafting procedures during the last ten years, no standard method has been adopted. This is quite natural since each operator prefers the method which has given him the best results, and it cannot be asserted that any one technic has demonstrated its superiority in all cases. It is improbable, furthermore, that standardization ever will be effected, since aside from fundamental principles each case is a law unto itself. This is particularly true of the wounded soldier with pseudarthroses and more or less loss of bone substance. Many of these patients are veritable surgical derelicts having passed through prolonged infections in a number of hospitals. When they finally present themselves for definitive treatment, foreign bodies may be present, the muscles may be atrophic or replaced by cicatricial cords, the nerves may have suffered a concomitant injury, the normal skin covering is deficient, the scar tissue is always the site of a latent infection and the general resistance is much impaired. A number of articles have been published giving the immediate results of operation, and it has been assumed that with a primary union and a smooth postoperative convalescence of several weeks, the involved bone has been restored to health and the neighboring joints to functional activity. In our experience such has not always been the case, and it is believed that the later results in a series of such cases, in which operation was performed consecutively without selection, would form a contribution of some value to the general fund of knowledge.

The patients whose cases are here presented were operated by us during the month of August, 1919, at United States Army General Hospital No 30, Plattsburg, N Y¹. Prior to June 15, 1919, this hospital had been used for psychiatric cases. At this time, with the closure of United States Army General Hospital No 10, at Boston, and the base hospital at Camp Devens, we received the residue of their surgical cases in the form of cases of ununited fractures and pseudarthroses which could not have previously been brought to the point of

1 Col J C Gregory, M C, U S Army, commanding

operation Our results are consequently representative of those which may be obtained in a military hospital rapidly adapted to a new line of work at a time when morale is considerably impaired by a growing desire on the part both of officers and patients for an early demobilization

GENERAL OBSERVATIONS

To eliminate some of the factors which make these late cases of bone repair a challenge to any surgeon, it has been found advisable to wait a sufficient length of time after the original infection for the tissues to establish a resistance and for the absorption of any remaining foci of infection Among the British surgeons, it was the practice to wait at least a year after complete healing before attempting bone repair In our cases the time intervening between the time of healing of the original wound and the operation was from three to thirteen months Two were performed at three and one-half months Of the three cases in which post-operative infection occurred, however, only one was a case of three and one-half months' duration and in the other two the time intervening in each had been eleven months

In the primary treatment of the lesion in most cases, there had been a fairly thorough débridement Without going into the much debated subject of total esquillectomy as opposed to conservative debridement, it may be said that those cases in which some bone fragments were left between the bone ends proved to be better suited for autogenous splinting because of the support furnished by the intervening framework of callus formed on the fragments These fragments were originally loose, but were attached to the main fragments by periosteum those without attachment to periosteum or other soft parts having been discharged as sequestrums

Exposure of the fragments and preparation of the field for the reception of the bone splint was the most tedious part of the operation The ends of the fragments were usually attenuated, and no plane of cleavage between scar tissue and bone could be found in this location Instead of commencing at the end of a fragment, it was consequently found more expedient to attack the shaft at a short distance from the end where the more normal tissues permitted easier approach to the periosteum The adherent scar tissue was then dissected and peeled from the periosteum toward the end of the fragment In one case in which a pocket of infection was discovered the operation was carried no farther than exposure of the fragments, the bone grafting operation being postponed to a later date There was but one such case encountered in our series and this case is not reported here because we did not have an opportunity to perform the final operation The English adopted this two-stage

procedure in all cases Albee² employs a course of massage preceding the operation in order to bring out latent infections All of our patients had had one or more courses of massage and many of them had undergone physiotherapy

The problem of reduction of the fragments arose in only a few cases since loss of bone substance with an interval of soft parts was the rule In the few cases of overriding fragments the reduction was directly effected by means of a strong lever An automobile tire iron served very nicely as a lever for the femur

These cases in which there were attenuated fragments and a lack of sound cortex were not suitable for inlay sliding grafts, and the method of application of the bone splint was consequently a matter of necessity rather than of election in most instances The superiority of the autogenous over the heterogenous bone splint has been so well established that this phase of the subject needs no discussion In all cases, the bone was taken from the cortex of the patient's tibia A combination of the intramedullary and cortical methods was used in five cases, the cortical in two, and the intramedullary in nine Three methods of holding the splints in place were used tight wedging, ligatures and bone pegs Intramedullary splints were made to fit tightly enough to prevent slipping, and in most cases they needed no other fixation Once, after an intramedullary graft was inserted, it was found necessary to put a bone peg through the cortex of the fragment in order to fix the graft and hold it in place Bone pegs and screws furnish a good means of fixation for cortical bone splints if three or more screws were used The minimum number of three is necessary to supply the three essential points of a lever fulcrum, power and weight Henderson,³ Ryerson⁴ and others have recently been using screws previously prepared from beef bone Ligatures of kangaroo tendon or strong catgut were used for lashing splints to the fragments in our cases of cortical and corticomedullary splints Grooves were cut in the cortex, or what remained of it, to receive the tibial transplant The ligatures were then swung around the entire fragment and tied securely over the splint, which gave good bony contact and sometimes firm fixation Albee² uses kangaroo tendon which he puts through drill holes in the cortex He states that this is absorbed in about forty days, and that the slight friction which it allows between the host bone and the graft stimulates the formation of callus

2 Albee, F H, and Weigel, E P Restoration of Loss of Bone, J A M A **74** 589 (Feb 28) 1920

3 Henderson, M S The Use of Beef-Bone Screws in Fractures and Bone Transplantation, J A M A **74** 715 (March 13) 1920

4 Ryerson, E W Intramedullary Beef-Bone Splints in Fractures of Long Bones, J A M A **73** 1348 (Nov 1) 1919

Postoperative care is of the utmost importance. In some of our cases of lesions of the humerus we had ready a plaster splint extending from the supraclavicular region down along the posterior aspect of the arm, elbow and forearm to the hand. This was molded over the shoulder and arm previous to the operation, and was dry and hard, ready for application after operation. Except in those cases in which the lesion was in the upper end of the humerus, the arm was bound to the chest in plaster over the molded plaster cast. In the three cases in which the bone splint was inserted with one end in the head of the humerus and the other in the shaft, the arm was put up in abduction at about 120 degrees (external cephalic angle), and was supported by a plaster cast with a wire triangle reinforcement under the humerus and against the chest. Cases of injury to the forearm were put up with the elbow at a right angle and in the neutral position of 90 degrees rotation. Plaster casts were used to maintain this position. The thigh and leg were immobilized in a cast when the operation was performed on these parts. Casts were left on seven weeks as a minimum time for the cases of injury to the humerus. All our patients wore a support of some kind at the time they passed from our supervision from one to nine weeks after operation.

The bones repaired were radius, 5 cases, humerus (shaft), 4 cases, humerus (surgical neck), 3 cases, ulna, 2 cases, femur, 1 case, and fibula, 1 case. A splint graft is not absolutely necessary for the fibula since after a loss of even several inches the leg recovers with good function. For pseudarthrosis of the upper end of the radius or lower end of the ulna, operation is not necessary since practically no loss of function results from these lesions.

Three patients developed postoperative infection, one due to disturbance of the external fixation and dressing on account of hemorrhage as mentioned below, the other two, presumably due to latent infection in the scar tissue.

REPORT OF CASES

CASE 1—A man aged 23, sustained multiple wounds from a high explosive which included a flesh wound of the left shoulder which speedily healed, and gave him slight discomfort only when he hyperabducted the left upper extremity. The main lesion was a perforating wound of the right shoulder, a shell fragment having entered the posterior aspect, 1 inch below the greater tubercle, making its exit at a point opposite on the anterior aspect and producing a compound comminuted fracture of the surgical neck of the humerus. Within a few hours debridement was performed under ether in a field hospital. Three months later, numerous sequestrums were removed, and the wound healed one month subsequently. When first seen by us the extremity was useless and had been on an aeroplane splint for one month. Nonunion was present although there was some callus. The wound had been healed for seven months.

and the parts had received prolonged massage and physiotherapy. An intramedullary splint was inserted at the site of the fracture, the bone being obtained from the cortex of the right tibia. The existing callus was not disturbed more than was necessary to expose the ends of the fragments, and no internal fixation was employed other than a tight fit. A splint was placed on the outer side of the humerus and the extremity was held to the side by plaster bandages. Sutures were removed on the eighth day, and both arm and leg wounds were found to be clean. On the tenth day, the arm was fixed in slight abduction by a plaster cast. Twenty-four days after operation there were two small discharging sinuses in the arm incision. When the hospital closed, eight weeks after the operation, one sinus was still present and the extremity was supported only by a Velpeau bandage. When seen by one of us fifteen weeks after operation, the sinus had been solidly healed for some time. The soldier could hyperabduct and circumduct the extremity, and his musculature was regaining its tone (Fig 1). Seven months after operation he reported his condition as "good."

CASE 2—A man, aged 26, sustained a gunshot fracture of the upper third of the left humerus. A sniper's bullet entered the anterior aspect of the arm just above the insertion of the deltoid and made its exit below the left scapula. After a first aid bandage had been applied he lay in a trench for two days without food or drink when he was taken prisoner. A plaster cast was then applied with his arm at right angles to the body. The wound healed without further attention and the cast was not removed until eight weeks later. At this time the arm was supported by a sling, but he was unable to move the upper extremity. About this time he had a severe attack of influenza. After his convalescence, he passed through several hospitals where he received massage and physiotherapy. At the time of operation the wound had been healed for nine months, but the upper extremity was useless. A splint of tibial cortex was forced in the upper fragment and fixed in the medullary canal of the lower fragment by a bone peg passing through both the fragment and the graft. This peg was necessary since a tight fit could not be secured and the graft showed a tendency to rotate in the lower fragment. There was no postoperative infection. Three weeks after operation, a fresh cast was applied with the arm in abduction, being held in this position by a wire gauze triangle in the axilla. Eight weeks after operation the graft had slipped down into the humeral shaft. Six months after operation, the soldier wrote, "No union. Need another bone graft."

CASE 3—A man, aged 23, sustained a gunshot fracture of the upper third of the right humerus resulting in nonunion with a 2 cm loss of substance. Seven months after the wound had healed, a splint of tibial cortex was tightly wedged into the medullary canals of both fragments. This patient had taken great care to keep up the muscular development of the injured extremity and during his convalescence did all he could to "hurry" his cure. The sutures were removed in eight days and the wound was dry and its condition was all that could be desired. About three weeks after operation, there was persistent hemorrhagic oozing from both arm and leg wounds for several days. Seven weeks after operation, when he passed from our observation, the union seemed to be firm. The arm was splinted and in the Velpeau position (Fig 2). When last heard from, seven months after operation, there was no union and a second operation was performed shortly thereafter.

CASE 4—A man, aged 23, sustained a gunshot fracture of the middle third of the left humerus. The wound healed in eight weeks, but the fracture did not

unite After the wound had been healed eleven months and massage and physiotherapy had been employed, a piece of tibial cortex was wedged in the medullary cavity of the lower fragment and laced in a cortical groove in the upper fragment The wounds were clean when the sutures were removed When he passed from our observation, there was still some motion present at the site of fracture When last heard from, seven months after the insertion of the bone splint, he reported that his arm was the same as before operation

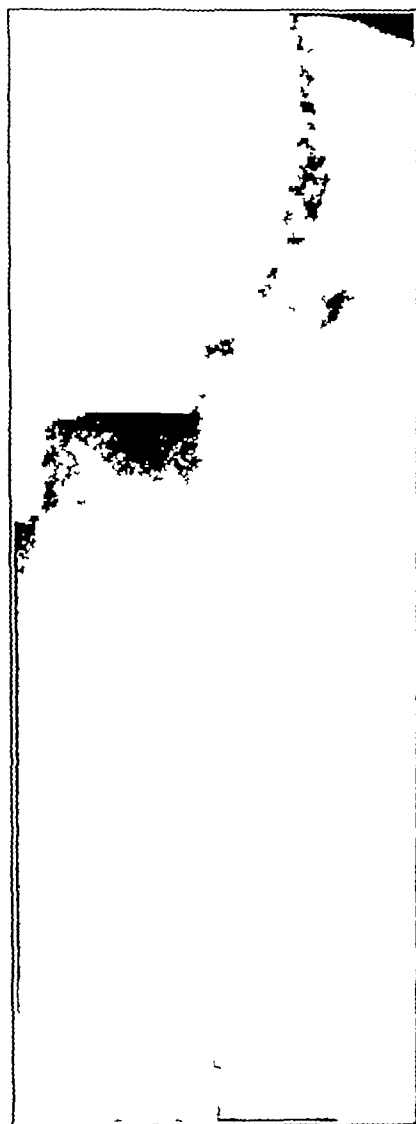


Fig 1 (Case 1) —Left humerus, twelve weeks after operation

CASE 5—A man, aged 27 sustained a gunshot fracture of the middle third of the right humerus The wound had been healed eight months and an unsuccessful bone graft had been performed four months previously A splint of tibial cortex was tightly wedged into the medullary canals of both fragments Five weeks later he was transferred to another hospital, the alignment was good and the extremity was in a cast A roentgenogram taken

eight weeks later, showed that the splint was broken at the site of fracture (Fig 3) Seven months after operation he wrote that "the graft did not take"

CASE 6—A man, aged 27, sustained a gunshot fracture at the junction of the middle and lower thirds of the left humerus Debridement was performed within twenty-four hours, and seven days later the bone was plated and a Thomas splint applied The plate remained in situ six weeks when it



FIG 2 (Case 3)—Left humerus, two months after operation

was removed, evidently on account of infection The wound healed eight weeks subsequently, and when first seen by us there was a pseudarthrosis of the left humerus with a loss of bone of 15 cm Three and a half months after the wound had healed and after the usual course of massage and physiotherapy, a piece of tibial cortex was tightly wedged into the medullary canals of both fragments, a molded splint was applied and the arm bandaged to the

side (Fig 4) As a result of latent infection, the splint became loose and was removed five months after its insertion When last heard from the patient was being treated expectantly

CASE 7—A man, aged 23, sustained a gunshot fracture of the surgical neck of the right humerus, a piece of shrapnel having entered through the triceps and having made its exit through the biceps at the upper third of the arm. The wound was badly infected and was treated with surgical solution of chlorinated soda (Dakin's solution) from the ninth to the seventeenth week, when the wound had completely healed During this period the greater portion of the head of the humerus had been removed from the wound as sequestrums A splint of tibial cortex was wedged into the remaining shell of the head of the humerus above, and into the medullary canal of the lower fragment below

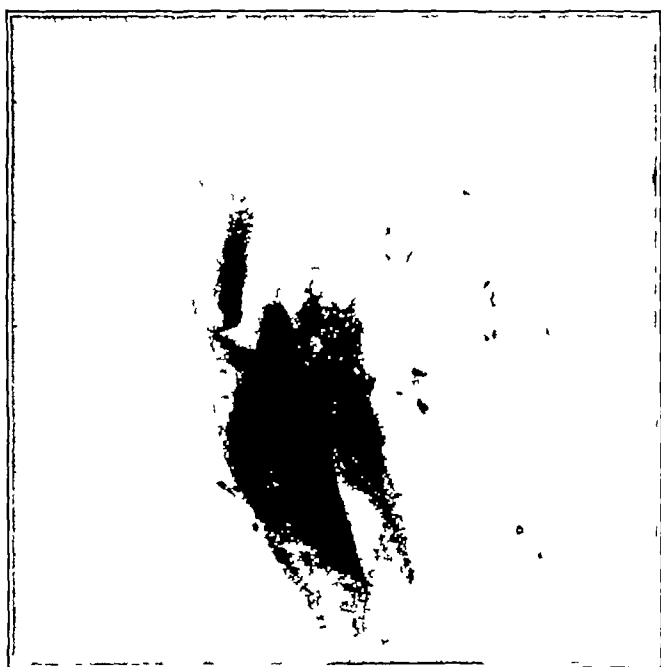


Fig 3 (Case 5)—Right humerus, three months after operation

During the next few days, the fixation had to be disturbed several times on account of continued oozing from inside the humeral head This led to movement of the upper end of the splint which caused more hemorrhage The remainder of the head, consisting only of the cartilaginous surface poorly supported by a thin layer of osteoporotic bone, made it impossible to secure solid fixation A vicious circle of hemorrhage, dressing, movement and more hemorrhage supervened which terminated in sepsis and the abandonment of the case to treatment with surgical solution of chlorinated soda

CASE 8—A man, aged 22, sustained a gunshot wound of the lower third of the left forearm with a compound comminuted fracture of the radius The left hand was abducted so that the ulnar styloid was 3 cm below the radial Five cm of the radius was missing, and rotation of the forearm was impossible The patient had received massage and physiotherapy, and the wound had been healed eight months An autogenous splint from the left tibia was wedged into a hole drilled in the lower fragment and into the medullary canal of

the upper fragment (Fig 5) Convalescence was interrupted, and when last heard from, six and a half months after operation, the patient reported the result as "good"

CASE 9—A man, aged 23, sustained a gunshot fracture of the left forearm which resulted in a loss of 3 cm of the middle of the shaft of the radius and consequent nonunion The soldier had received massage and physio-

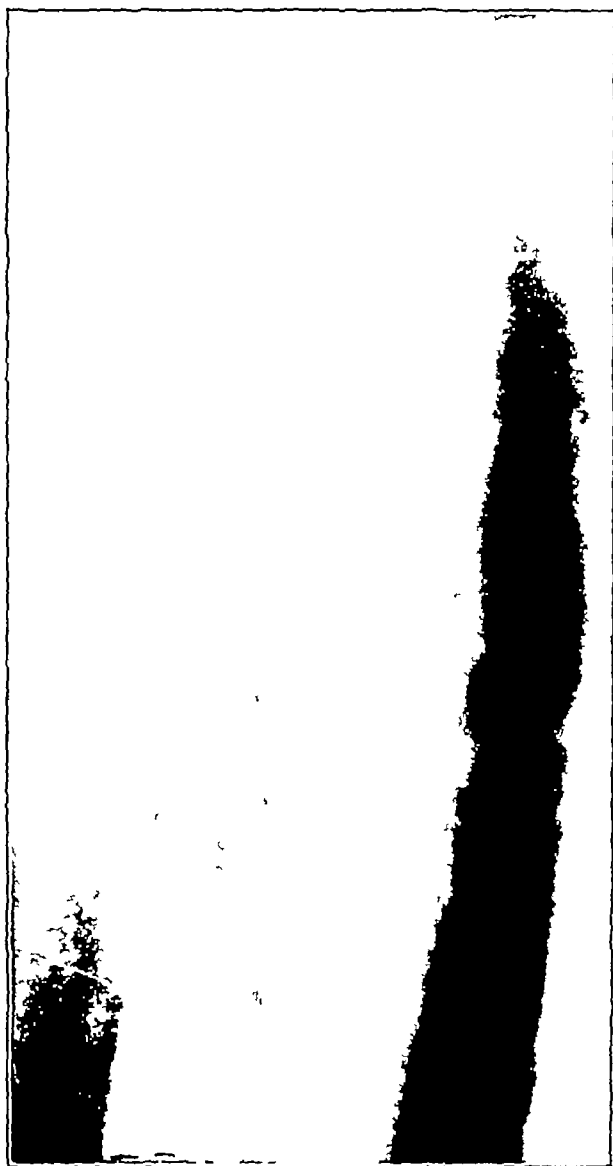


Fig 4 (Case 6) —Left humerus, five weeks after operation

therapy, and the wound had been healed for three and a half months A splint of tibial cortex was wedged into the medullary cavities of both fragments, and the extremity encased in plaster Three weeks later when he passed from our observation alinement was good, and union was progressing satisfactorily In a letter written to us more than five months after operation, the patient said that he had done well until the preceding week when he had fallen and broken the radius at the site of the new union

CASE 10—A man, aged 38, in a collision sustained a simple fracture of both bones of the left forearm at the junction of the middle and lower thirds. Five months later there was malposition and faulty union and the fracture of the radius was reduced by open operation, holes being drilled in the fragments and kangaroo tendon being used to hold them in place. Four months later, as there was no union, a splint of tibial cortex was wedged into the lower frag-

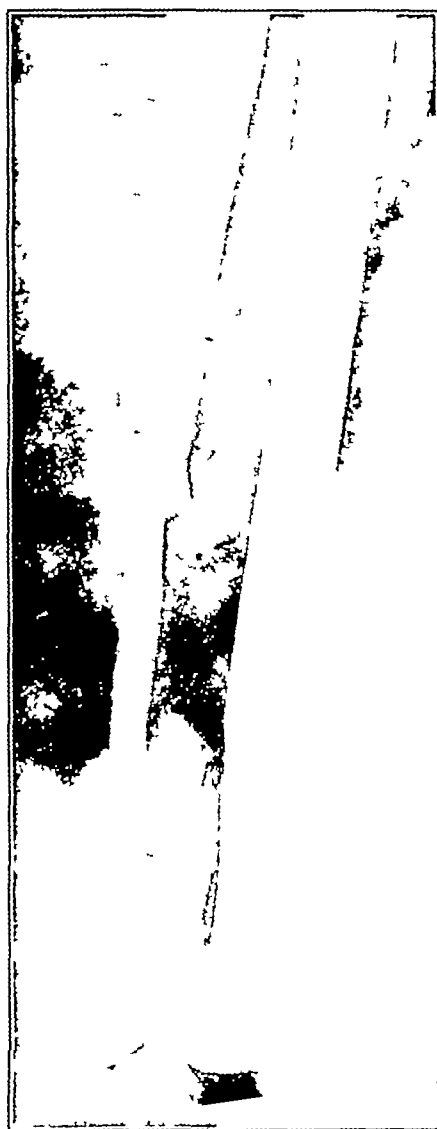


Fig 5 (Case 8)—Radius, six weeks after operation

ment and laced in a cortical groove in the upper fragment. The ulnar fracture seemed to be the site of a fibrous union and was not disturbed. When he left our observation, nine weeks later there was some backward bowing of the radius, but union seemed firm. Six months after operation when last heard from, he wrote that 'the upper end of the graft was loose but the union was progressing'.

CASE 11—A man, aged 31, sustained a gunshot fracture of the lower third of both bones of the left forearm. Debridement was at once performed, and six months later, a sequestrectomy. Two months after healing, during which time the patient received physiotherapy and vigorous massage, a tibial transplant was placed in the radius to bridge a defect of 6 cm. This tibial splint was wedged into the medullary canal of the upper fragment and laced with

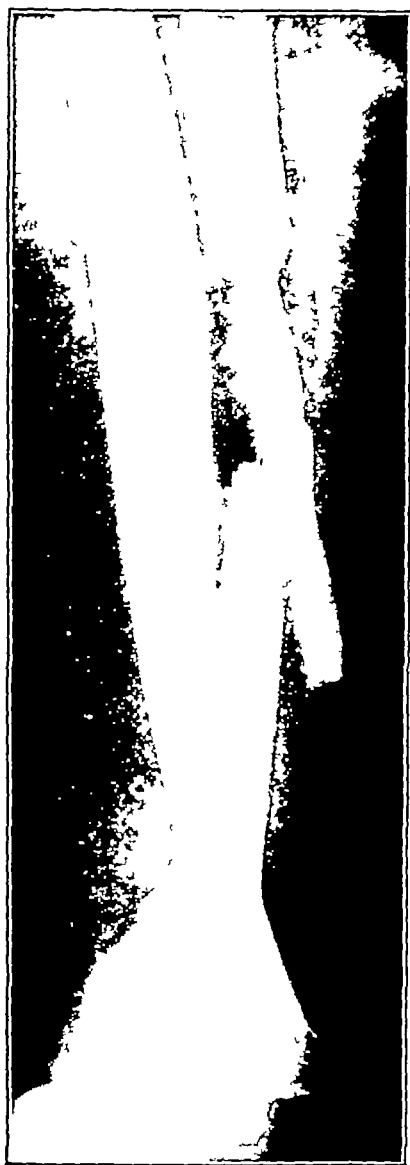


Fig 6 (Case 11)—Left forearm, six weeks after first operation

kangaroo tendon in a cortical groove in the lower fragment. The ulnar fragments were joined by a fibrous union and were not disturbed. The patient did well, and one month later was transferred to another general hospital where his splint was inadvertently removed almost immediately after his arrival. When I next saw him, two weeks later, the splint had slipped out of the groove in the lower fragment and the condition was that illustrated by Figure 6. We performed a second operation, twelve weeks after the first,

when the upper end of the splint was so firmly incorporated with the proximal fragment that it was difficult to tell the one from the other. The lower end of the splint was brought back to its former bed in the distal fragment, but was fractured while being laced in position with kangaroo tendon. A second splint was then taken from the tibia and one end wedged in the distal fragment. The other end was laced to the original splint which had become incorporated with the proximal fragment. Three months later the roentgen

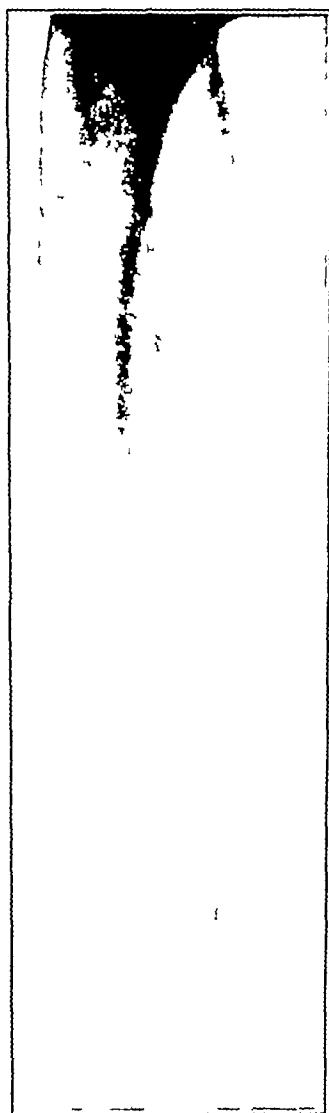


Fig 7 (Case 11)—Left forearm, three months after second operation

ray revealed some suggestion of union between the two transplants and the patient had about 45 degrees of combined pronation and supination (Fig 7). When last heard from, six months after the second operation, the patient reported that his forearm was 'the same as before operation'.

CASE 12—A man, aged 20, sustained multiple shrapnel wounds of the left leg and right arm and forearm. There was 5 cm missing from the middle

third of the right radius with resulting nonunion. When he first came under our observation, the wound in the left leg was not quite healed. The forearm had been healed seven months and was held in pronation. Active supination was impossible, but about 50 per cent of passive supination was present. The hand grip was weak. After massage and physiotherapy, a splint of tibial cortex was wedged into the medullary canal of the upper fragment and mortised in a groove in the cortex of the lower fragment where it was securely held by a lacing of kangaroo tendon. A cast was then applied from the middle of the humerus to the metacarpals, the elbow being flexed at a right angle. The wound almost immediately showed evidences of sepsis, and cultures revealed a streptococcus. It was concluded that the infection had been liberated from the scar tissue at the time of operation. When the patient passed from our observation, six weeks later, the wound was still septic and the upper end of the splint was loose.

CASE 13—A man, aged 28, sustained a gunshot fracture of the middle third of the left ulna which resulted in a loss of substance of 5 cm and conse-



Fig 8 (Case 13)—Left ulna, one month after operation

quent nonunion. Three months after the wound had healed, during which time the patient received the usual preliminary massage and physiotherapy, a splint of tibial cortex was tightly wedged into the medullary canals of both fragments. The patient passed from our observation one month later, at which time the graft was in good position and the alinement was perfect (Fig 8). When last heard from, five and a half months after operation, he said that there was good union at one end but that the other end was still ununited.

CASE 14—A man, aged 24, sustained a gunshot fracture of the middle third of the left ulna with considerable loss of substance. After the wound had been healed for thirteen months, during which time the patient had received several courses of massage and physiotherapy, the ulnar defect was bridged by a tibial transplant. A mortise was cut in both fragments, and the transplant was wedged in and tied in place by kangaroo tendon. The forearm was put up in moderate pronation. Six weeks later the union was apparently firm, but the cast was still strapped to the extremity (Fig 9). When seen by one of us (W H T), three months after the operation, the result seemed to be satisfactory in every way.

CASE 15—A man, aged 21, sustained a simple fracture of the right femur in a motorcycle accident. When he came under our observation, seven weeks after the injury, there was posterior angulation and an overriding of 15 cm

After the overriding had been overcome by direct leverage with a piece of automobile spring, a splint of tibial cortex was wedged into the medullary canal of the upper fragment and laced with kangaroo tendon in a cortical groove in the lower fragment. The extremity was encased in plaster, the cast extending from the costal margin above to the toes below. Five weeks after operation, when the patient was transferred, the approximation was good and there was some callus present. When last heard from, nine months after operation, he was walking, and the result was all that could be desired.

CASE 16—A man, aged 32, sustained a gunshot fracture of the middle third of the right fibula with a loss of substance of 4 cm. There was numbness over the dorsum of the foot, and dorsiflexion was impaired from weakness and involvement of the muscles in the peroneal scar and by contraction of the Achilles tendon. The wound had been healed four months, and the patient had received vigorous massage and physiotherapy. The anterior tibial

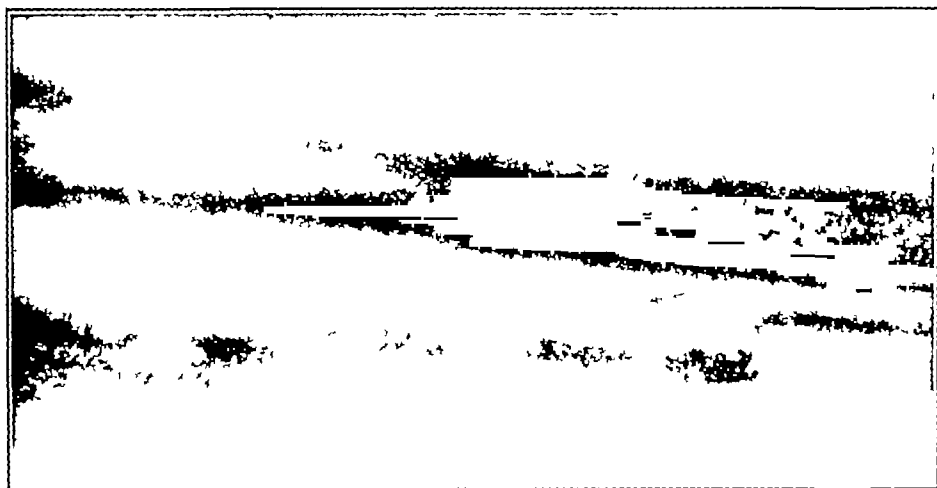


Fig 9 (Case 14) —Left ulna, three months after operation

nerve was freed from the scar, the Achilles tendon was divided and a tibial transplant was wedged between the cleared ends of the fibular fragments. The extremity was put up with the foot at right angles to the leg. Recovery was uneventful. When last heard from, nine months after operation the patient said that his leg was as good as it had ever been.

CONCLUSIONS

- 1 It is possible for an intramedullary autogenous splint to become an integral part of the host's bone. This is shown by Case 11, in which we had an opportunity to observe the result of a previous bone graft operation. The proximal fragment and the upper end of the transplanted bone had grown together and appeared as one bone (Fig 6). Transplanted bone is, then, not always absorbed.

- 2 In our cases the most frequent cause of failure was sepsis; the next in frequency was slipping of the internal bone splint.

CHRONIC DUODENAL DILATATION

ITS CONCOMITANT AND SEQUENTIAL PATHOLOGY

HUGH CROUSE, M D

EL PASO, TEXAS

Chronic duodenal dilatation is a frequent pathologic condition. This assertion is based, not alone on clinical observations, but also on the well known anatomic faults of the adult human duodenum. Normally the human duodenum has practically no mesentery, it is fixed dorsally by an abundant retroperitoneum, is indented in front and behind by blood vessels and is impinged on by contiguous structures. The quadruped has a long mesentery and freely movable duodenum. Comparative study shows that the human is paying the price of a potentially pathologic condition for the upright posture.

Embryologically, the human duodenum has a long mesentery and consequently free movement. Should the adult retain this condition the major etiologic factors of pathologic conditions of the duodenum would be removed.

The duodenum of the thirty to sixty day embryo is occluded by a vacuolated epithelial plug. Synchronous with the solid state of the gallbladder and cystic ducts, the first portion of the small bowel has a developmental condition not characteristic embryologically of any other portion of the small intestine. The vacuolated mucosa presents the potential etiology of duodenal diverticula found in the adult. The embryologic budding of contiguous structures into the dorsal and ventral mesogastrium draws the human duodenum partially into the position found in later life. However, part of the location in the adult is due to the upright posture and to Nature's effort to provide support for a structure subject to strain. The retroperitoneum fixes it, and as this shortens with the body's growth the last two thirds of the duodenum, through the medium of ligamentary developments and pancreatic growth, gradually assumes the adult position.

Histologically, the first 12 inches of the small bowel varies markedly from the rest of the lesser intestine. It contains all of the muco-membranous structures of the rest of the small bowel, namely villi, glands of Lieberkuhn, and mucous secreting cells, yet in addition to these, beneath its mucomuscular layer, are the glands of Brunner—a chain of isolated, racemose, bifurcating tubular glands. These secretory structures extend only slightly beyond the duodenojejunal angle, and are therefore rightly classified as strictly duodenal features. Comparative studies of these glands reveal a marked variation as to the

number present in different animal species, they are markedly scattered in the truly carnivorous type, fairly close together in the omnivorous and exist as almost a perfect sheet in the truly herbivorous, particularly the sheep. Such a comparative study would lead to the inference that the glands of Brunner are essential in car-



Fig 1—Normal relationship of first third of duodenum to pancreas and liver

bohydrate digestion. When considering the etiology of glycosuria, further deductions from these facts lead one to believe that a diseased condition of the duodenum may favor the development of diabetes.

The first 4 inches of the duodenum has quite a different physiologic function to perform than have the second and third portions. Linked with the pylorus of the stomach at its beginning and having

the entrance of the common duct and the duct of Wirsung at its end, it receives a frankly acid chyme at its origin and an intensely alkaline secretion, derived from the liver and pancreas, at its termination

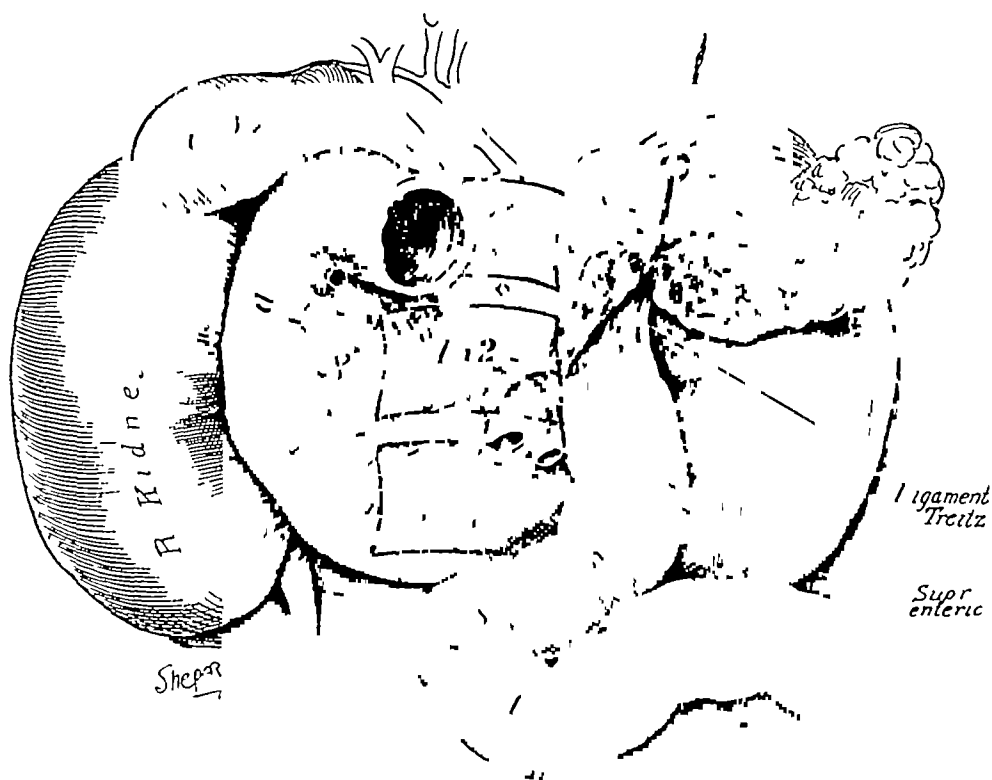


Fig 2—Normal C-shaped duodenum and the relationship of the superior mesenteric vessels to the last third of the duodenum, head of pancreas, gall-bladder and kidney

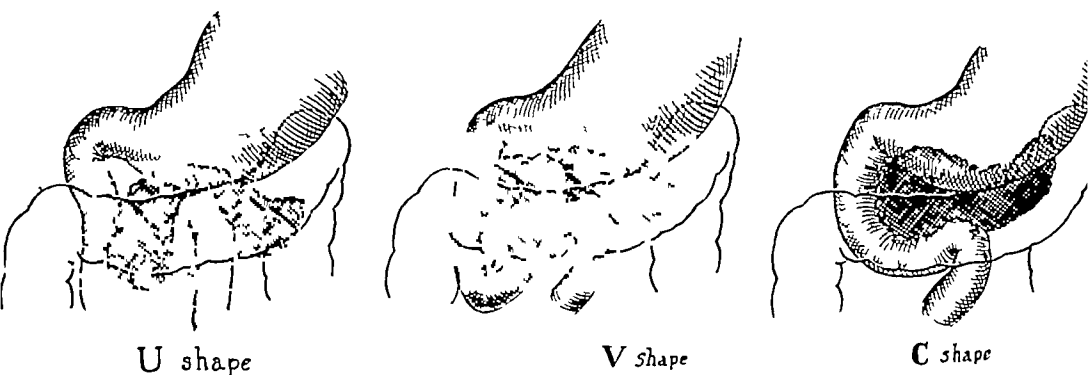


Fig 3—The three forms of duodenum U and V, pathologic, C, normal

This portion of the duodenum necessarily must serve as a transitional, anatomic, physiologic structure between the stomach and the small intestine proper

The first 4 inches of the bowel have a complex function to perform, which is in no sense equaled by other parts of the duodenum, or the entirety of the small intestine

Considerable clinical and physiologic evidence leads one to infer that the duodenum possesses racemose gland features with hormone qualities. Starling's isolation of prosecretin and secretin the former changing by acid contact into the latter, sheds a light on the physiologic functions of the first portion of the duodenum. Considered at first as a probable enzyme further tests particularly its failure

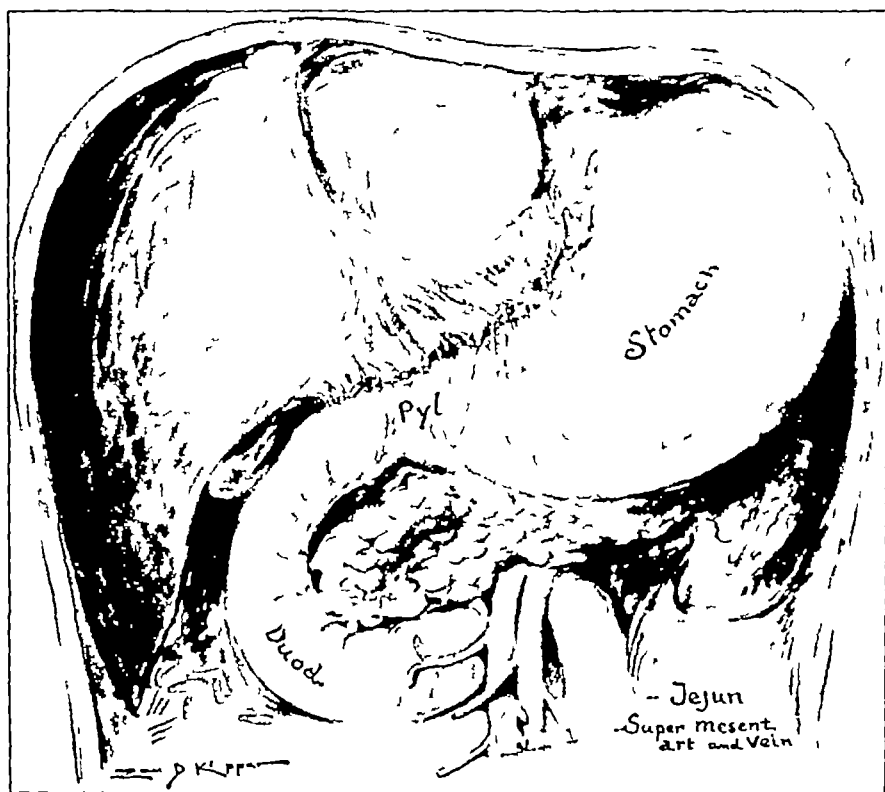


Fig 4—Normal anatomy of the stomach and duodenum and contiguous structures

to be destroyed by heat, prove secretin to be, in all probability, a hormone. It has been demonstrated that this substance has several qualities. One stimulates the nerve mechanism of the pancreas with a consequent free flow of the pancreatic juice, another, a chemical entity, has intense acid neutralizing powers. Other secretin principles seemingly aid in gland interchange in establishing the normal when deficient, complicated pathologic conditions of the body may develop. The failure of the normal secretory functions of this portion of the duodenum would result in an improper digestive ability on the part

of the bile and the various enzymes of the pancreatic juice, due in the main to a deficient neutralization of the acid chyme with the necessary chemical change of the weaker alkalines by the more active acid stomach content. The sequence would be an amylaceous indigestion, a faulty fat transformation, failure of proteid change, a flatulent state, an intestinal indigestion, and, consequently, a poorly nourished body.

Maury,¹ in 1909, by a series of animal experiments, apparently showed that the duodenum, particularly the first third, was essential

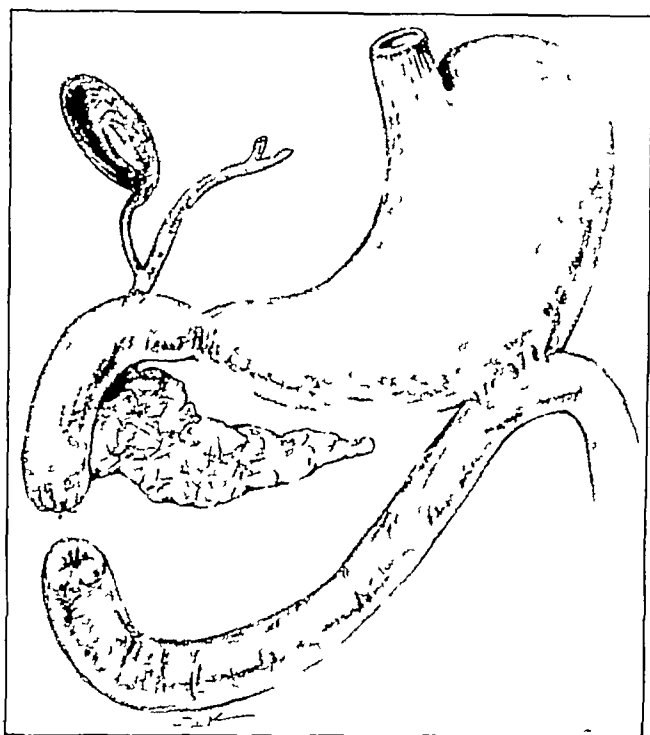


Fig 5—Maury's experiments on animals

to life. Despite careful transposing of the biliary and pancreatic ducts into a lower intestinal site, or connecting them with the stomach, duodenectomy resulted almost uniformly in death within seventy-two hours. The transposition of these ducts into a new location, after isolating them from the duodenum, did not produce death. The transfer of these ducts into a new location and the constriction of the duodenum lowered the vitality of the animal but did not kill it.

Matthews, in 1912, in the Lowe Laboratory, repeated these experiments with similar results and arrived at a similar conclusion. Moore—

1 Maury, J W D. Intestinal Obstruction. An Outline for Treatment Based on the Cause of Death, *Am J M Sc* **137** 725 (May) 1909

head and Landes,² in the Lowe Laboratory, recently repeated these experiments on dogs and refuted Maury and Matthews' conclusions. Mann and Kawamura in the research department of the Mayo Clinic, in a large series of duodenectomies on various animals, arrived at conclusions similar to those of Moorehead and Landes. Despite the conclusions of the last four experimenters, clinical evidence sustains the belief that the duodenum is a complicated structure with vital functions. The rapid heart and anuria, subnormal temperature, obstipation and intense symptoms of shock associated with acute duode-

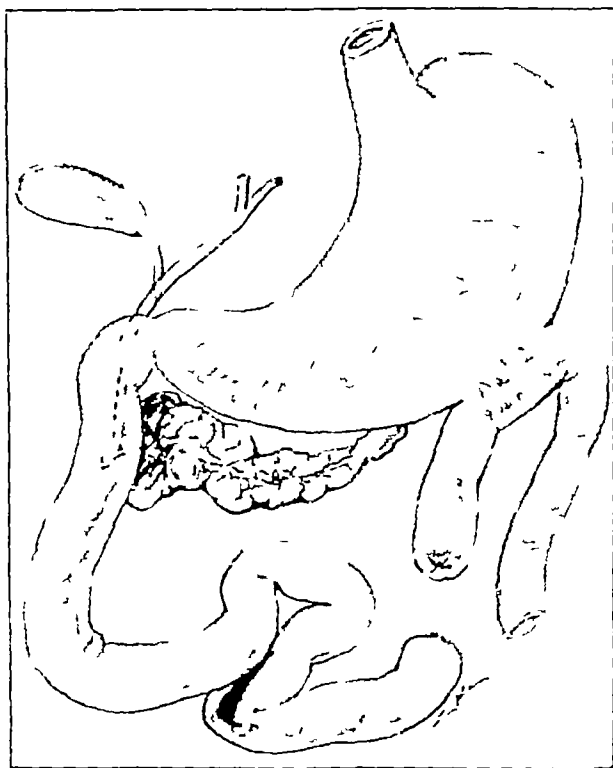


Fig 6—Experimental steps of Maury, 1909

nogastric dilatation suggest that a secretion is formed by the duodenum which stimulates the vagus and lowers vasomotor tone.

The normal curve of the human duodenum simulates the curve of an Old English letter "C". Such a type rarely becomes dilated unless there exists a constrictive agent such as an embryologic band passing from the gastrohepatic omentum to the undersurface of the liver and gallbladder, or an adhesive band of a developmental nature, from the transverse colon passing over the duodenum to the gallbladder and liver.

² Moorehead, I. I. and Landes, H. E. Duodenectomy: A New Method. J. A. M. A. 72: 1127 (April) 1919.

The other two forms of the duodenum are the "V" and "U" type, each of which has pathologic possibilities. The former, on account of its low position, when accompanied by a gastrocolonic ptosis may give rise to symptoms which simulate those of chronic appendicitis. I have observed sixteen such cases, in each of which operation had been performed by others for chronic appendicitis with no relief to the patient.

Dwight,³ of Harvard, has demonstrated beautifully by means of wax filling, the various forms and indentations of the human duode-

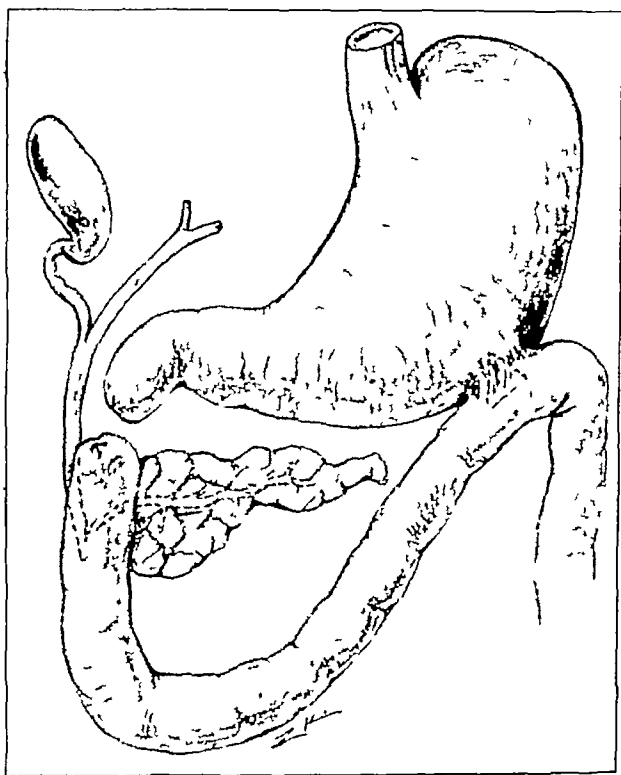


Fig 7—Experimental steps of Maury, 1909

num and also the diverticula which may develop from it. His studies cover various stages from the infant to the adult.

Several fixation features of the adult type of the duodenum have potential points of pathology. Its first portion, which is partially covered by the peritoneum, normally has some movement, its inferior end is pressed on by the head of the pancreas and is covered by the transverse colon when the latter is in normal position. The beginning portion of the second part is also pressed on by the head of the

³ Dwight, Thomas. Observations of the Duodenum, *J Anat & Physiol* **31** 516, 1896

pancreas, is almost entirely overlapped by the normally located transverse colon, and, at its juncture with the third portion, is indented behind by the second lumbar vertebra. The third portion is indented on its posterior surface by the inferior vena cava and abdominal aorta, while the superior mesenteric vessels compress it from the front. The last two thirds of the duodenum are fixed posteriorly by the retroperitoneum. The last third passes through a fold at the upper part of the mesentery where the retroperitoneum forms superiorly and inferiorly two folds, called the superior and inferior duodenal

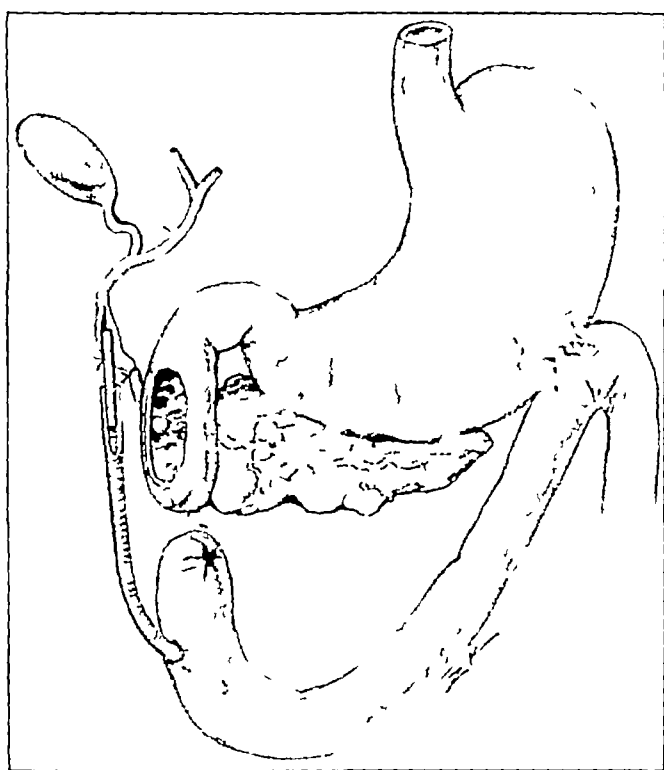


Fig 8—Experimental steps of Maury 1909

folds. The duodenum at this point enters into the arbitrarily named second portion of the small bowel, the jejunum. At this junction, on account of the retroperitoneal development of the ligament of Treitz, there exists a force indirectly fixing to the diaphragm the duodeno-jejunal angle. The ordinary sweep of the jejunum into the left renal fossa does not produce a marked but rather an obtuse angulation of the small bowel. Should the jejunum drop directly down, an acute angulation occurs with a subsequent pathologic dilatation of the duodenum.

ETIOLOGY OF CHRONIC DUODENAL DILATATION

The etiology of chronic duodenal dilatation listed according to the frequency of each form is

(a) Ptosis of the transverse colon, either alone or accompanied by gastric displacement, inducing through the mesenteric drag an approximation of the superior and inferior duodenal folds as well as a pull upon the ligament of Treitz

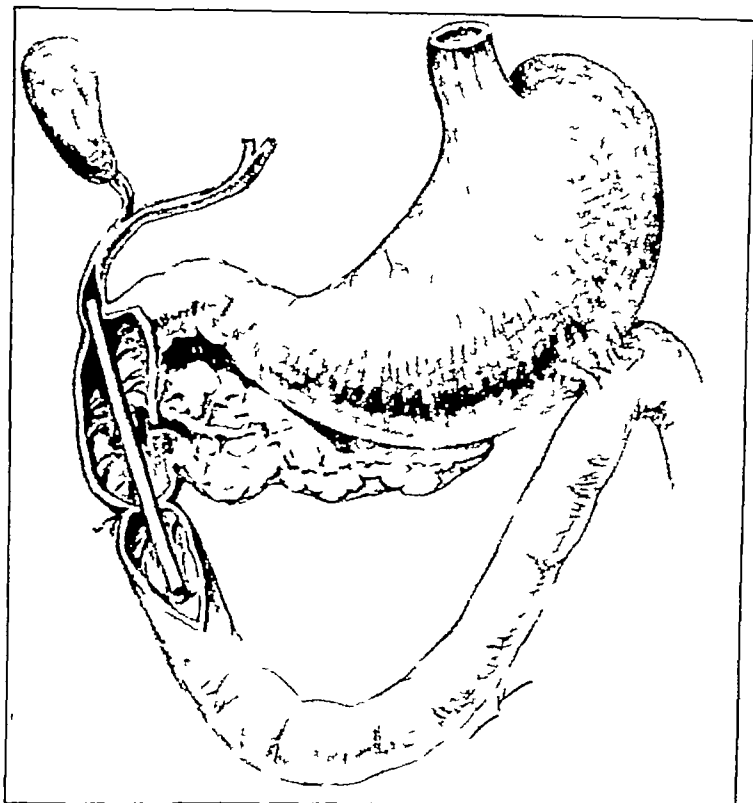


Fig 9—Experimental steps of Maury, 1909

(b) A small bowel with short mesentery which prevents bony support in the pelvis for the intestines, producing duodenojejunal constriction similar to that of chronic ptosis, yet in addition to this, there is a pull on the superior mesenteric vessels which causes constriction of the last third of the duodenum

(c) A jejunum dropping perpendicularly instead of having the normal sweep of the bowel into the left renal fossa, such direct drop produces a sharp angulation of the duodenojejunal angle

(d) Embryologic remnants of the gastrohepatic omentum that pass from the pylorus to the gallbladder and undersurface of the liver with a constriction of the first third of the duodenum as a result

(e) Developmental bands of adhesions from the transverse colon to the gallbladder, liver or pylorus, partially constricting the duodenum, the constriction of the adhesion in front acting with the vertebra behind as a resisting point

(f) Diverticula of the duodenum and other obstructing factors are not uncommon. Many roentgenograms interpreted as revealing duodenal ulcer represent only this pathologic intestinal eversion.

(g) Troubles at the head of the pancreas, such as cysts, hematomas,

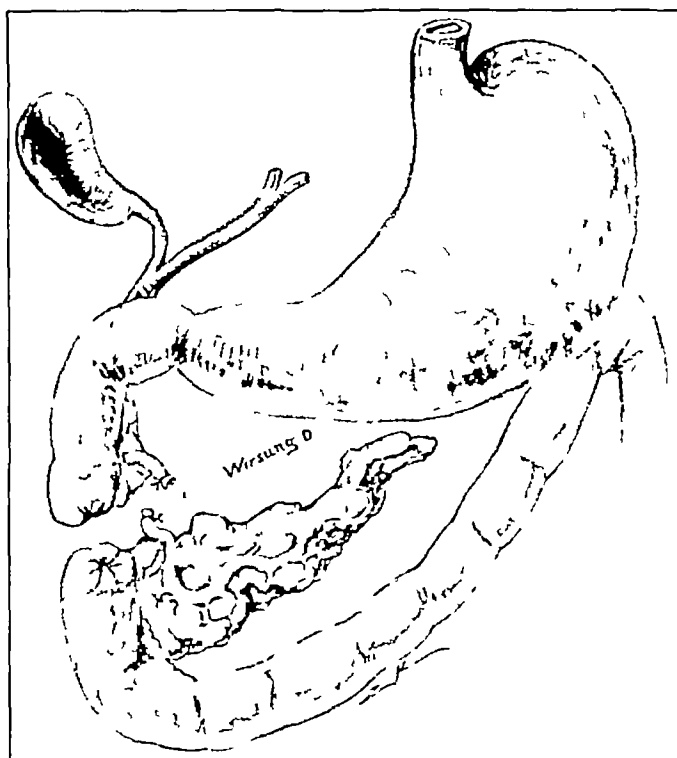


Fig 10—Experimental steps of Maury, 1909

malignant growths and interstitial changes of the gland which, as it enlarges, impinges on and compresses the first and second portions of the duodenum.

(h) Exaggerated stimulation of the nerve supply of this portion of the intestine at times occurs as the result of pathologic conditions lower down. Such a nerve stimulation induces a clonic bandlike action on the part of the circular muscular fibers of the duodenum and if long continued produces duodenal dilatation. Ochsner's⁴ duo-

⁴ Ochsner, A. J. Constriction of the Duodenum Below the Common Duct, and Its Relation to Disease, *Ann Surg* 43:80 (Jan.) 1906. Constriction of the Duodenum Below the Common Duct and Its Relation to Disease, *Tr Am Surg A.* 23, 1905.

denal bands have been demonstrated by Boothby⁵ to be simply thickenings of the muscular coat. Such bands have been proved to occur only occasionally in the second and third portions of the duodenum.

SYMPTOMATOLOGY

The symptomatology of chronic duodenal dilatation is marked by distress in the right half of the epigastric region, at first occurring nearly always from three to four hours after a meal. Ultimately this symptom becomes constant, varying only in its degree of severity.

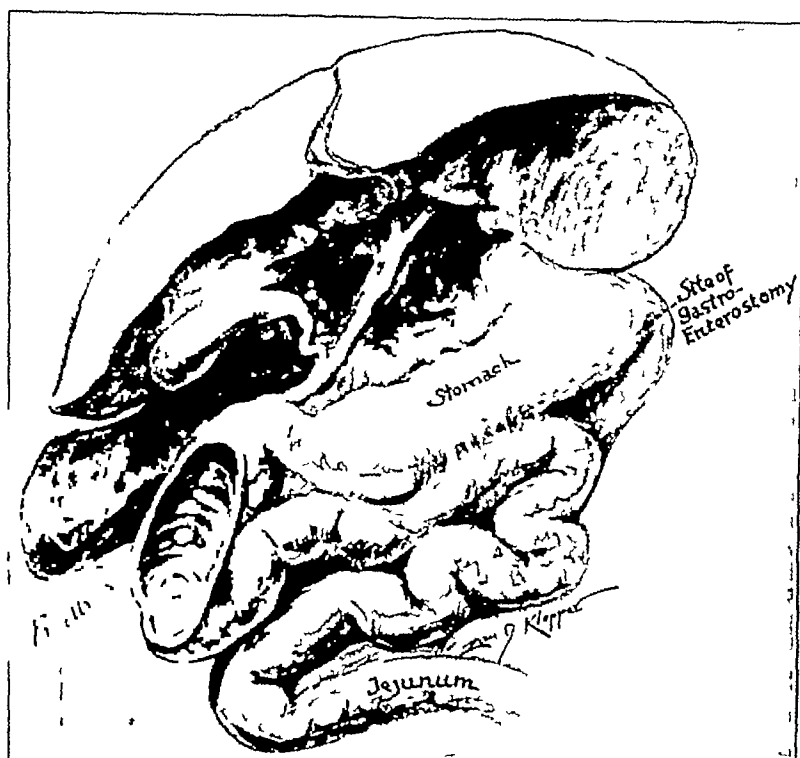


Fig. 11—Experimental steps of Maury, 1909

There are belching, marked autointoxication, accompanied by constipation, an irritable, rapid irregular heart, which cannot be explained by a cardiac disturbance or by exophthalmic goiter, neurasthenia, headache of a hemicranial type and scanty urine of high specific gravity, not always laden with indican.

The diagnosis of chronic duodenal dilatation is based on the clinical history with these symptoms plus careful roentgen-ray examinations. Roentgenograms should be taken serially, ten to twenty

⁵ Boothby, W. M. The So-Called "Ochsner Muscle" of the Duodenum, Boston M. & S. J. 157:80 (July 18) 1907.

minutes apart, for an hour, and then a six-hour roentgenogram taken in a prone, lateral posture, as for motor inadequacy of the stomach. Hayes' deep percussion test over the right rectus muscle in the area bounded by the liver to the right, the normal transverse colon line below, and the pylorus to the left, gives an unnatural, gaslike note

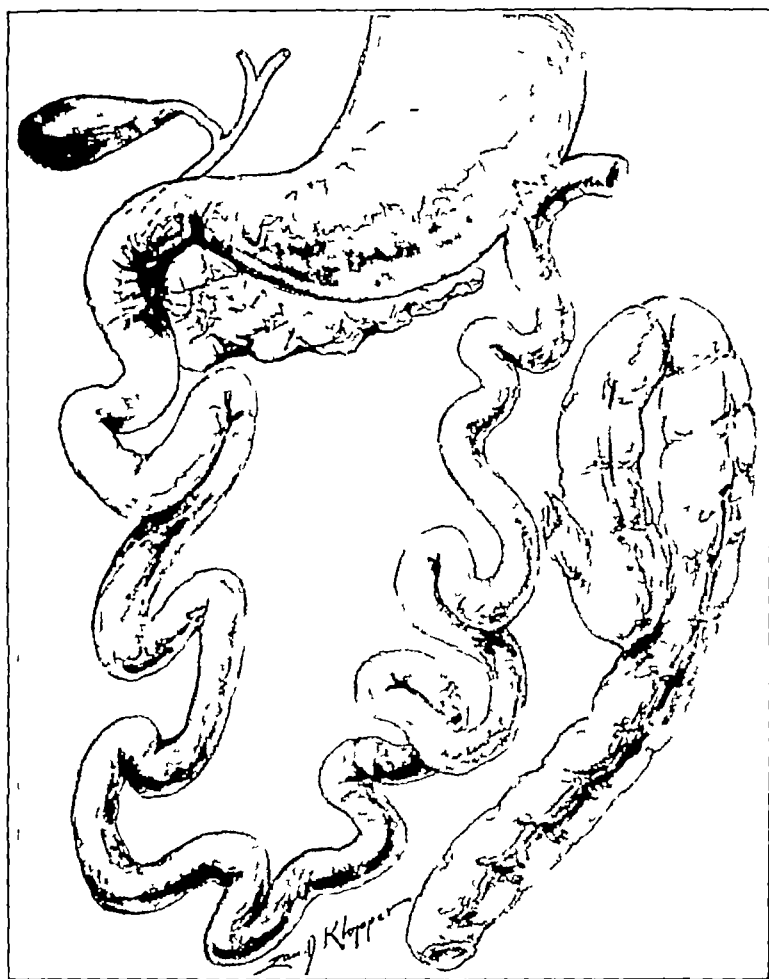


Fig 12—Experimental steps of Maury, 1909

when duodenal dilatation exists. The paradoxical pressure test of Hayes⁶ is made practically as Quimby's⁷ drag, only the diagnostician makes the pressure pull to relieve duodenojejunal constriction, thus allowing the duodenal gas content to pass into the jejunum while

6 Hayes, W. V. V. *Chronic Intestinal Stasis*, New York M. J. **119** 170 (Jan 24) 1914.

7 Quimby, A. J. *Chronic Intestinal Stasis*, New York M. J. **119** 162 (Jan 24) 1914.

listening, with the stethoscope, for the phenomena at the normal point of junction of these two portions of the small bowel

Testing for starch in the stools and Einhorn⁸ duodenal content tests complete the methods that I use to differentiate other right hypogastric troubles from chronic duodenal dilatation. The concomitant pathology is dilatation or atony of the stomach which is only too frequently classified as an isolated instead of an accompanying trouble. The sequential pathology is extensive. The reversal of the flow of duodenal contents from intestine to stomach leads to marked digestive disturbance. The dilatation of the duodenum obstructs the normal output of the glands of Brunner, which results in a faulty

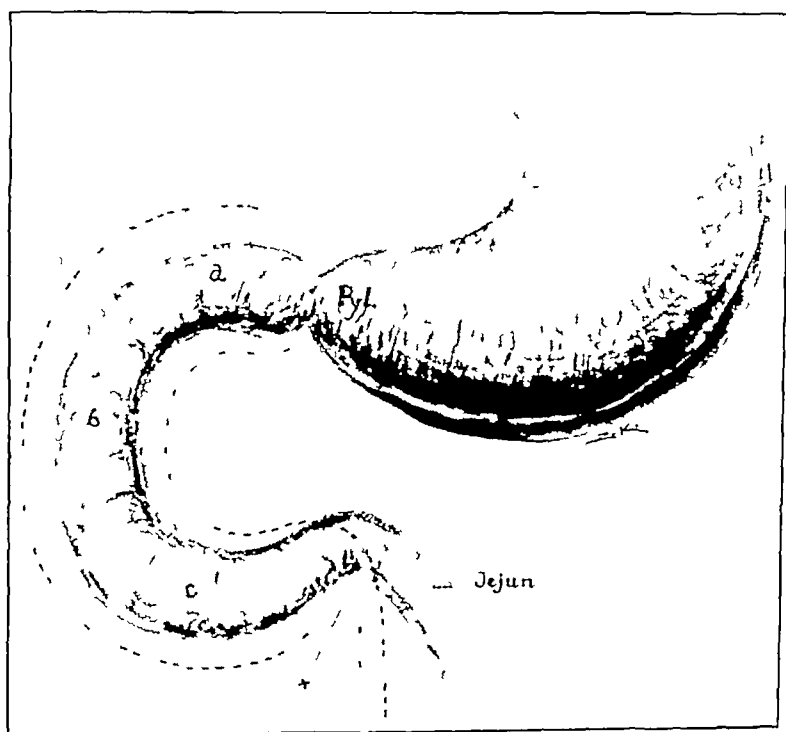


Fig 13—Normal sweep of jejunum into left renal fossa. Dotted line shows results of drop of jejunum with consequential dilatation of the duodenum

secretin development with a sequential lack of alkaline neutralization, hence, amylaceous indigestion, flatulency, toxicosis, cardiac, nerve, ocular, cerebral and renal troubles, hemicrania, exophthalmic goiter and at times idiopathic epilepsy are found. A history with a symptomatology covering these major points, particularly a story of chronic gastric trouble and intestinal stasis, should lead the diagnostician to investigate the duodenum

⁸ Einhorn, Max. Historical Sketch of the Development of the Duodenal Tube, *Am J M Sc* **151** 202 (Feb) 1916

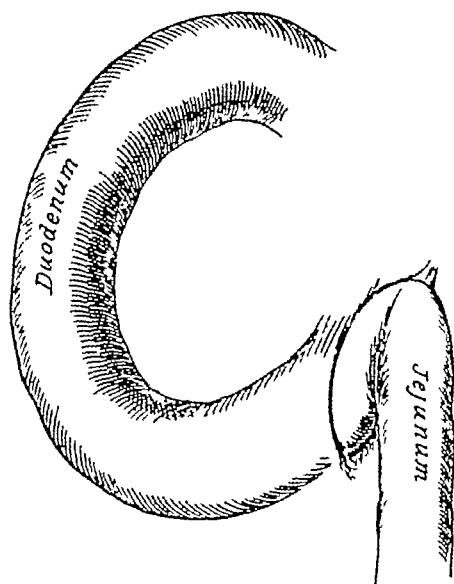


Figure 14

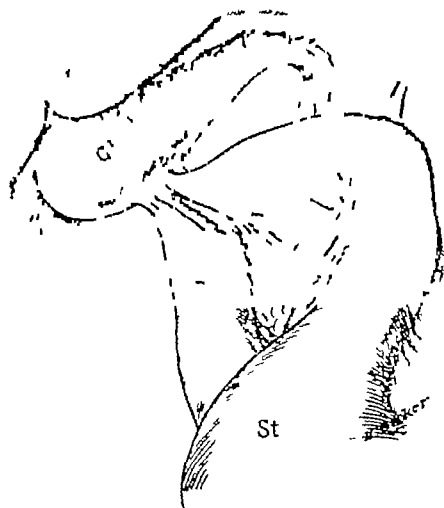


Figure 15

Fig 14—Duodenojejunal angle superior and inferior folds, with direct dropping jejunum

Fig 15—Angulations of the duodenum, produced by an old duodenal ulcer, attached by adhesions to the gallbladder

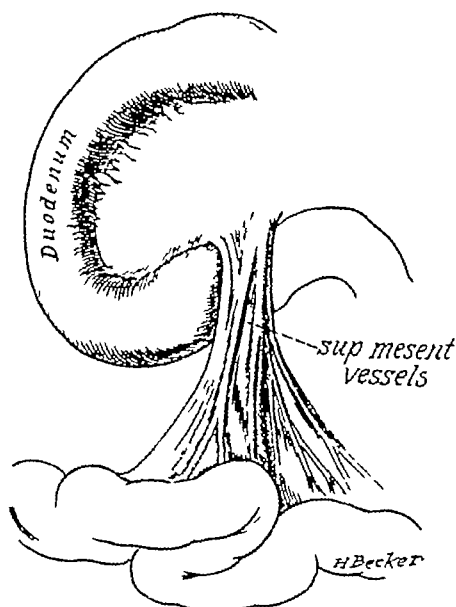


Figure 16

Fig 16—Short mesentery constriction of the duodenum by superior mesenteric vessels

The treatment of chronic duodenal dilatation is medical, mechanical and surgical. The positive correction of this trouble is a purely surgical procedure. I have been able, however, to give a large per-



Figure 17

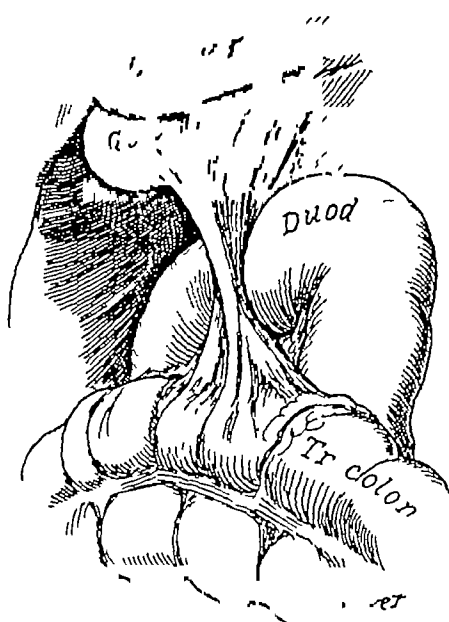


Figure 18

Fig 17—Developmental band from gastrohepatic omentum, passing from the pyloric end of stomach to gallbladder, constriction of first third of duodenum

Fig 18—Developmental band following ulceration of transverse colon passing over duodenum to gallbladder, causing constriction

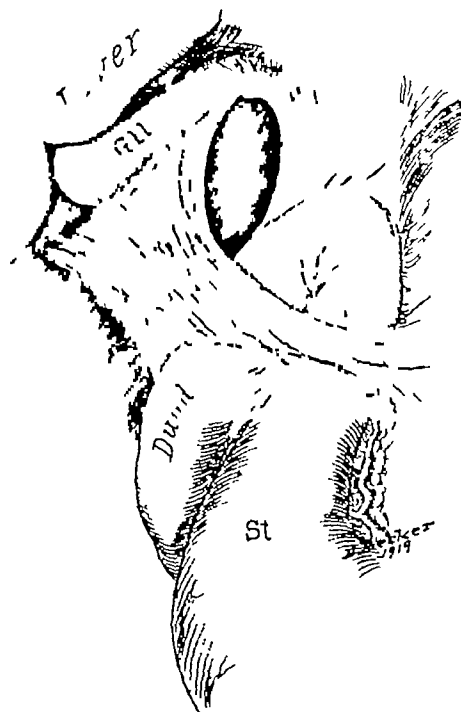


Figure 19

Fig 19—Embryologic band from gastrohepatic and greater omentum, showing the blood vessels existing in an embryologic structure instead of absence of blood supply as is the case in developmental bands, which produces duodenal stasis and dilatation

centage of my patients marked relief by the following means first, rest, and rest in a recumbent posture, demanding that the patient, two hours after each meal, assume the knee-hand position for from ten to fifteen minutes, in order that the mesenteric pull may be removed Then



Fig 20—Gastroptosis, anterior view, showing angulation of duodenum, ptosis of transverse intestine with consequential drag on right kidney

the patient turns to the right side and, with the hips elevated, the passage of the duodenal content to the jejunum is stimulated instead of being emptied reversely into the stomach or remaining in the obstructed bowel The patient is given a carefully selected composite

nitrogenous, glucose charged, carbohydrate diet Foods are selected for their low ferment and high fat producing qualities Broiled steaks, mutton chops, chicken, breakfast bacon, soft boiled and poached eggs, roast beef, medium well done, roast mutton and chicken, stale or

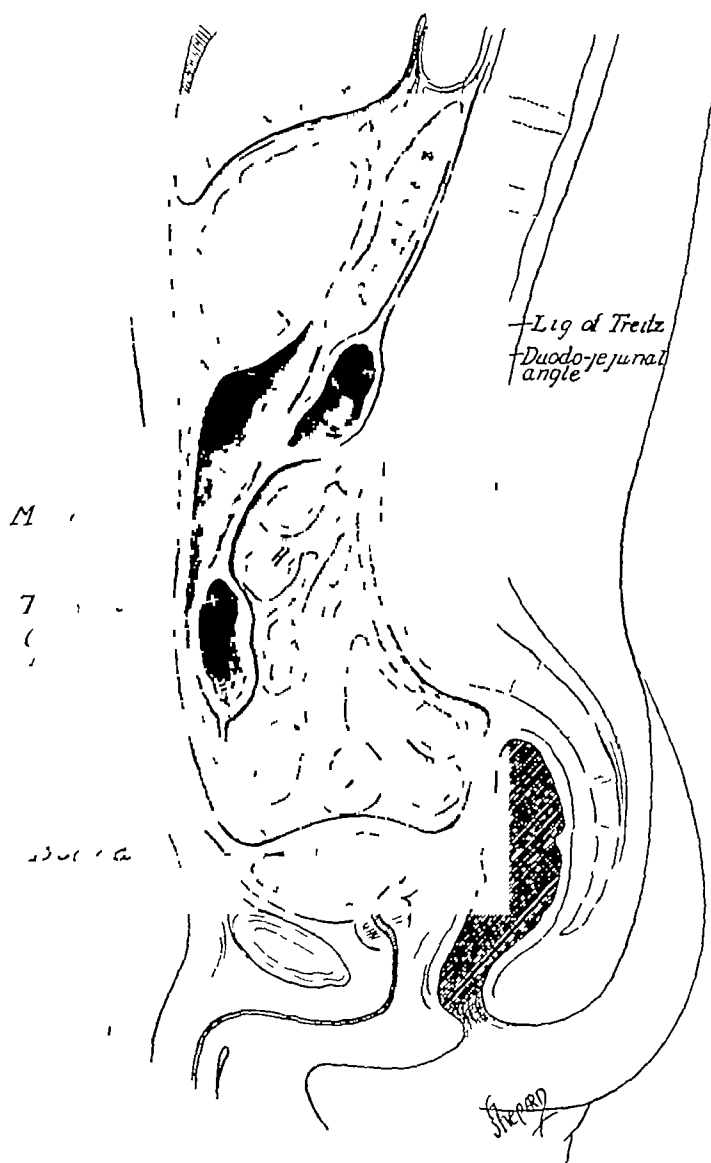


Fig 21—Transverse colon ptosis with constriction by ligament of Treitz, Bloodgood pathologic condition

toasted white bread, baked or boiled Irish potatoes, butter in abundance, lettuce, spinach, toasted cereals, rice (Chinese style), sweet milk and cream, if there does not exist an idiosyncrasy to them, are recommended After the completion of each meal, a raw, salted egg, covered with orange juice is taken

To commence with, if possible, a pure milk diet is given, and the change is gradually made to the diet mentioned while the patient is still in bed. When the patient is permitted to be up, a mechanical support made of ducking is fixed inside a front-laced corset and applied before



Fig 22—Billroth's duodenojejunostomy, improper technic

the patient arises and while in the heel-shoulder position, in the meantime the stomach is dragged up, as a woman with a pendulous abdomen confines her too abundant abdomen while lacing a corset. In fact, the same method is used as when dealing with the gastrocolonic ptosis as far as the support goes.

Before food, the following prescription, or a variation of it, is given

R	Tinct belladonnae foliorum	℥ iii
	Tinct nucis vomicae	℥ v
	Tinct cardamomi compositae	℥ x
	Aquae destillatae	q s ad fl ʒ i

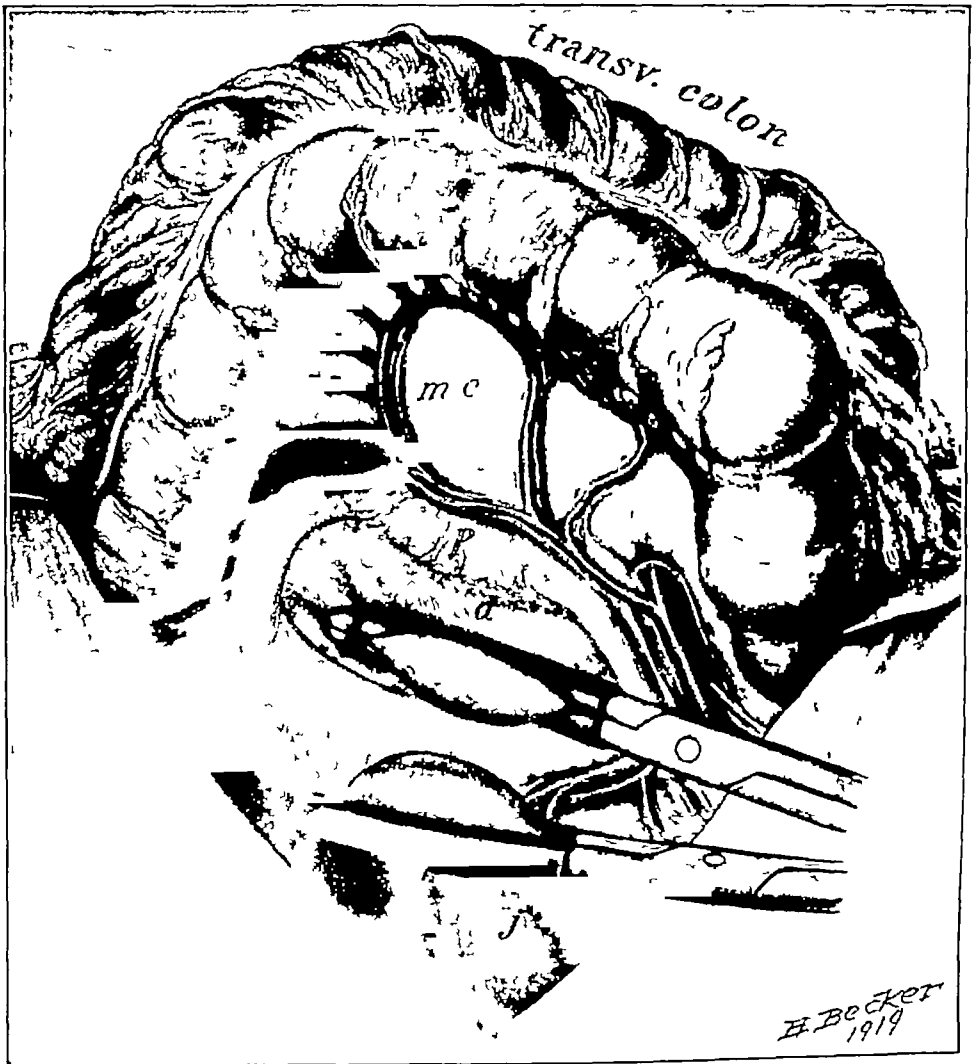


Fig 23—Bloodgood-Crouse suggestion second third of duodenum and jejunum approximated

After the ingestion of food this prescription is given

R	Magnesi oxid	ʒ iv
	Sodii bicarbonatis	ʒ iiss
	Olei menthae piperitae	q s ad fl ʒ iv
M	Sig One teaspoonful in half a glass of water	

The former is given to check the excessive secretions and relieve spasms, and the latter to neutralize excessive acidity

During the entire course of the treatment the duodenal Einhorn lavage is utilized, consisting of 16 ounces of a 3 per cent hypertonic

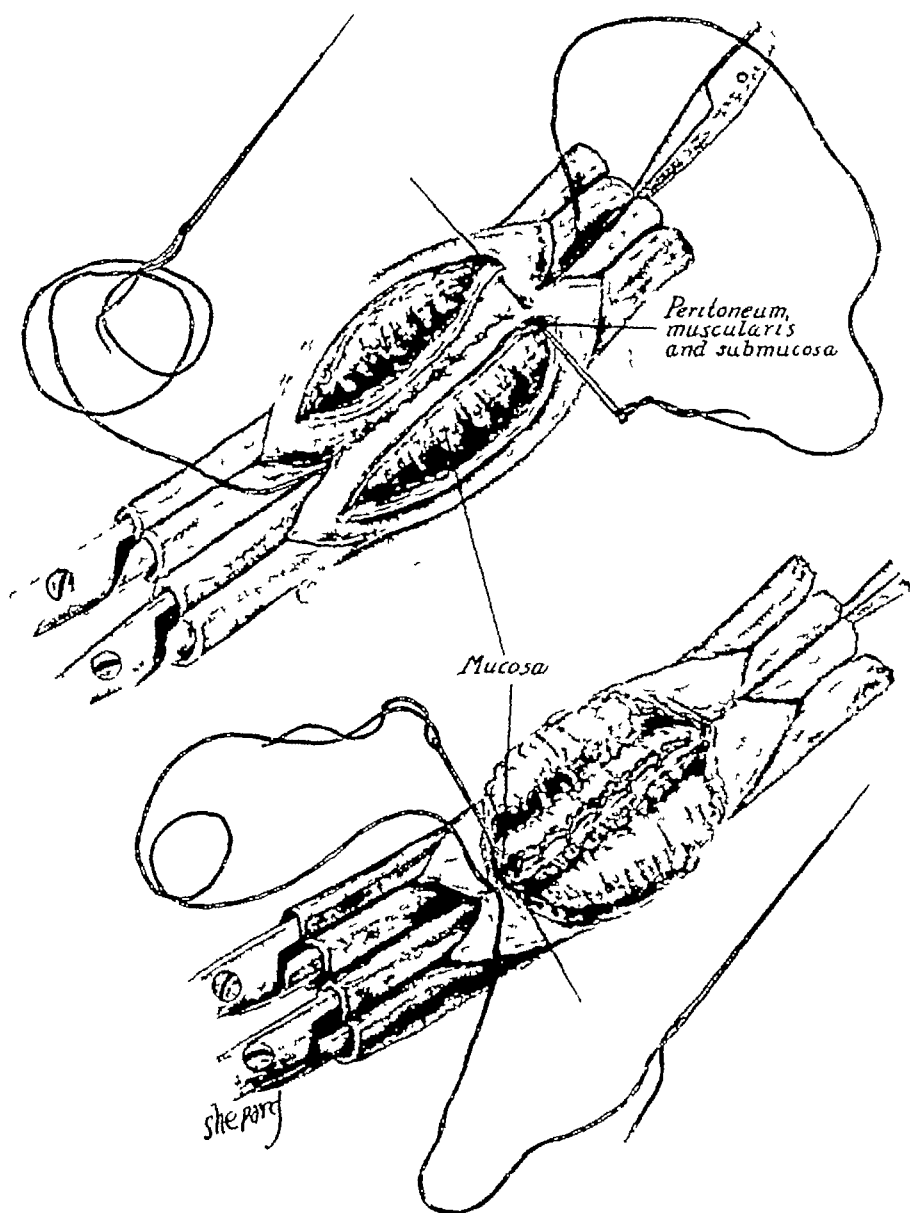


Fig 24—Methods of approximation

salt solution, which contains 2 drams of sodium sulphate. This is done each morning and is easily accomplished provided the patient is encouraged to sip a half to one teacupful of warm water while the tube is still in the stomach, to encourage the passage of the tube

into the intestine. The tube is lowered until the yellow, golden-colored, duodenal content appears, and subsequent to such appearance the lavage is started, this should occupy about twenty minutes. This should be done daily for about a week, then on alternate days and thus gradually the intervals should be lengthened, but the procedure should

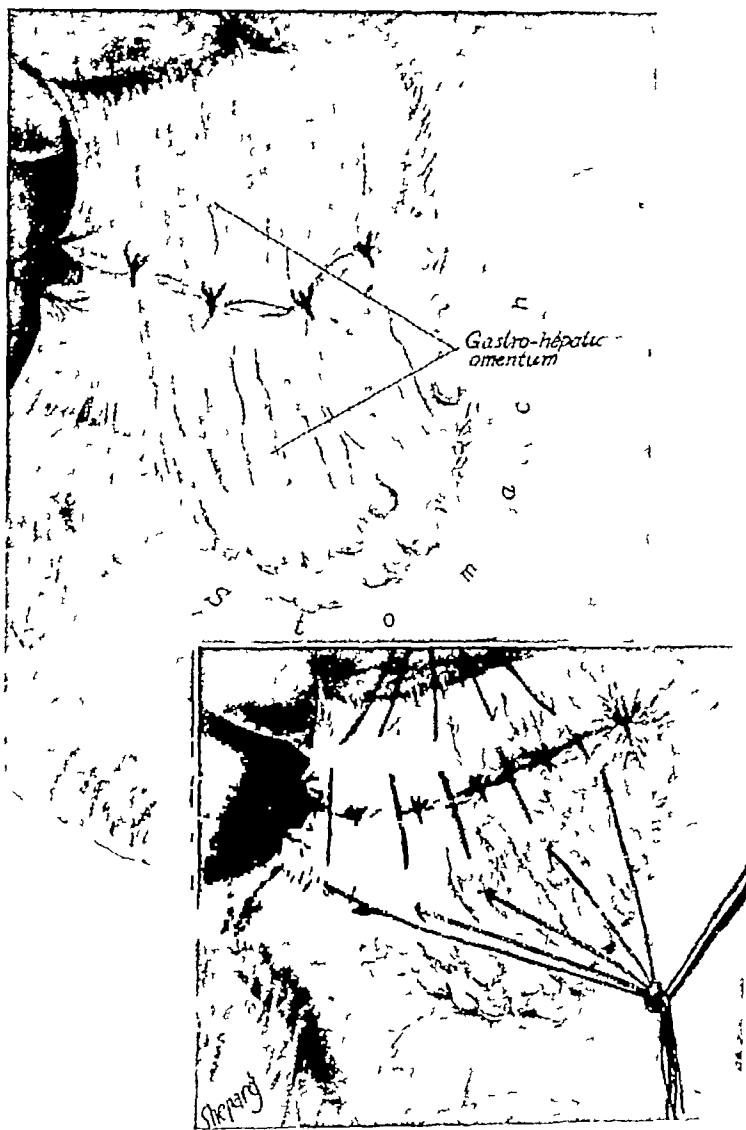


FIG 25—Bayes operation for shortening the gastrohepatic omentum

be repeated occasionally for months. As a rule within two or three hours after the lavage, two or three copious watery stools occur resulting in a feeling of well-being.

While one can expect alleviation through these methods in the ordinary case, the real curative treatment is strictly surgical. Surgical intervention should, of course, consist in removing

the causes whether they be embryologic or pathologic bands, ptotic colon alone or stomach displacements as well. In gastrocolonic misplacement the Bayes operation plication of the gastrohepatic omentum, amplified by my reinforcement of it by utilizing the so-called falciform ligament, is the method of choice. The falciform and round ligaments are detached from their umbilical and abdominal wall attachments, leaving the diaphragm and liver fixation points alone. The falciform ligament, which is but an embryologic winglike fold of the abdominal peritoneum, is split and sutured with the raw

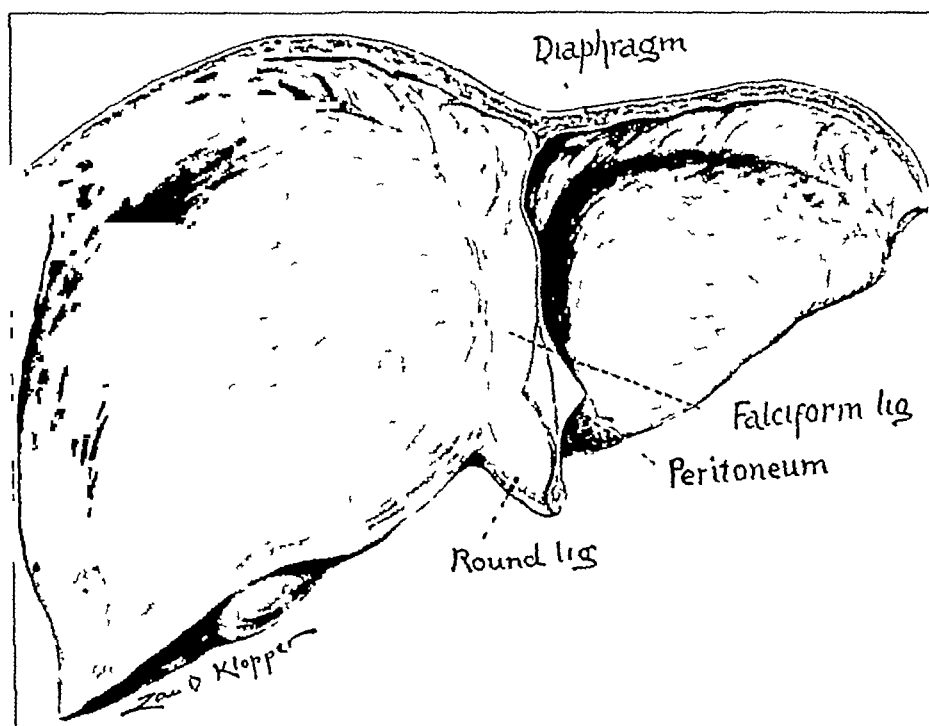


Fig 26—Falciform ligament, showing relationship of the falciform ligament to diaphragm and liver

surface downward, together with the round ligament, over the plicated gastrohepatic omentum with No 1, twenty-day chromic catgut. Adhesions should be dealt with according to their nature.

A cholecystectomy is indicated when a gallbladder is markedly thickened and adherent. I am still at a loss to know how to deal with a raw-surfaced gallbladder, except by its removal, thus avoiding the reforming of adhesions. The Bloodgood⁹ method of performing a par-

⁹ Bloodgood, J. C. Dilatation of the Duodenum. *J. A. M. A.* 59:117 (July 13) 1912, Acute Dilatation of the Stomach. Gastro-Mesenteric Ileus, *Ann Surg.* 46:736, 1907.

tial colectomy in duodenal dilatation caused by ptotic colon has, in his hands, led to successful results. A developmental or congenitally dilated colon should be removed when co-existing with the duodenal dilatation.

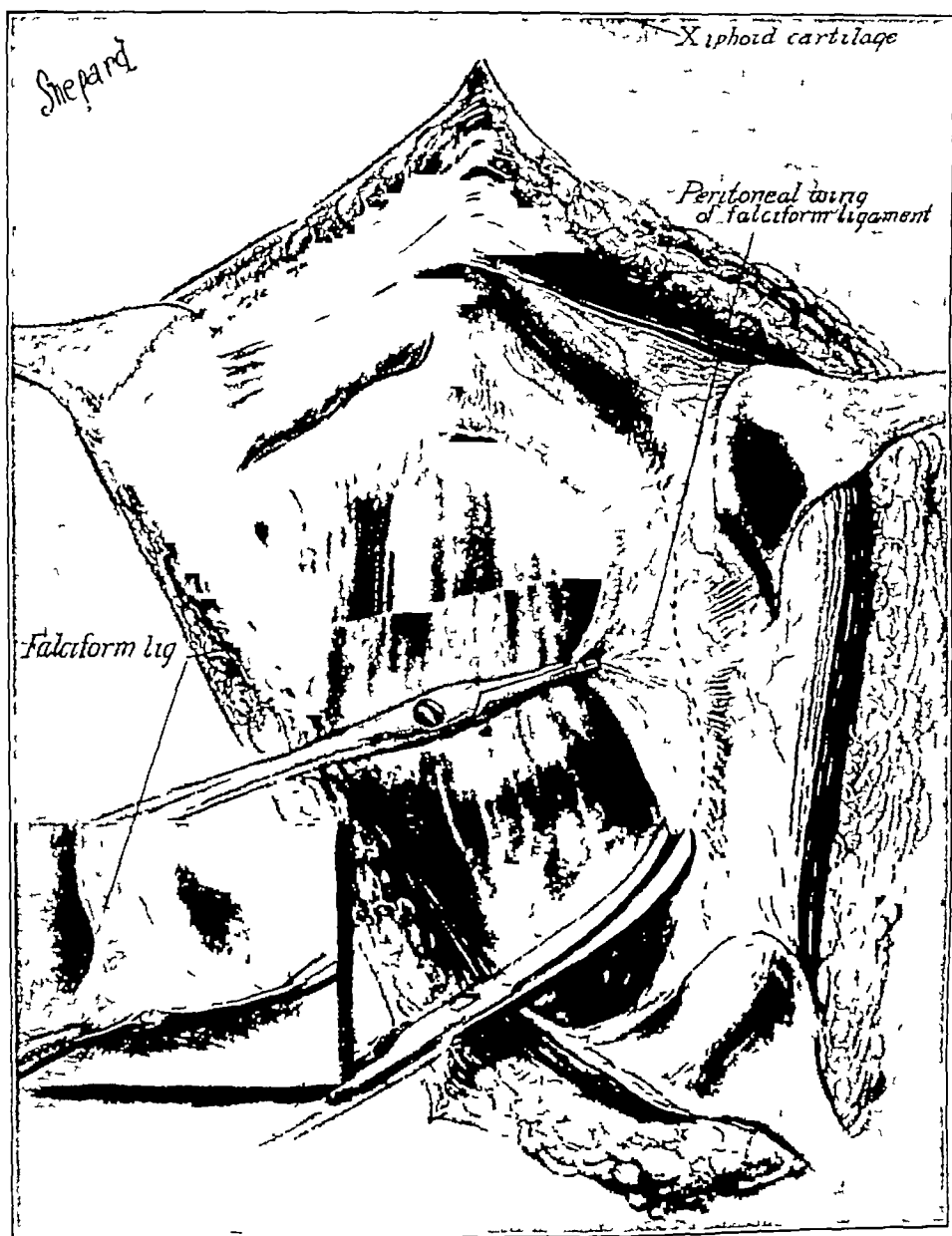


Fig 27—Crouse technic utilizing the falciform ligament and its peritoneal wing. Inset shows method of stretching before splitting.

The logical course to pursue in all cases of widely dilated duodenum, as suggested by Bloodgood and followed by Stively in 1910, is to perform a duodenojejunostomy of the lateral apposed type (not the Billroth utilization of the first third of the duodenum, with its

consequential need of tearing through the gastrocolic omentum in order to approximate the jejunum to the duodenum), an approximation of the second third of the duodenum with the jejunum under the temporarily elevated transverse colon. A direct drain of the important

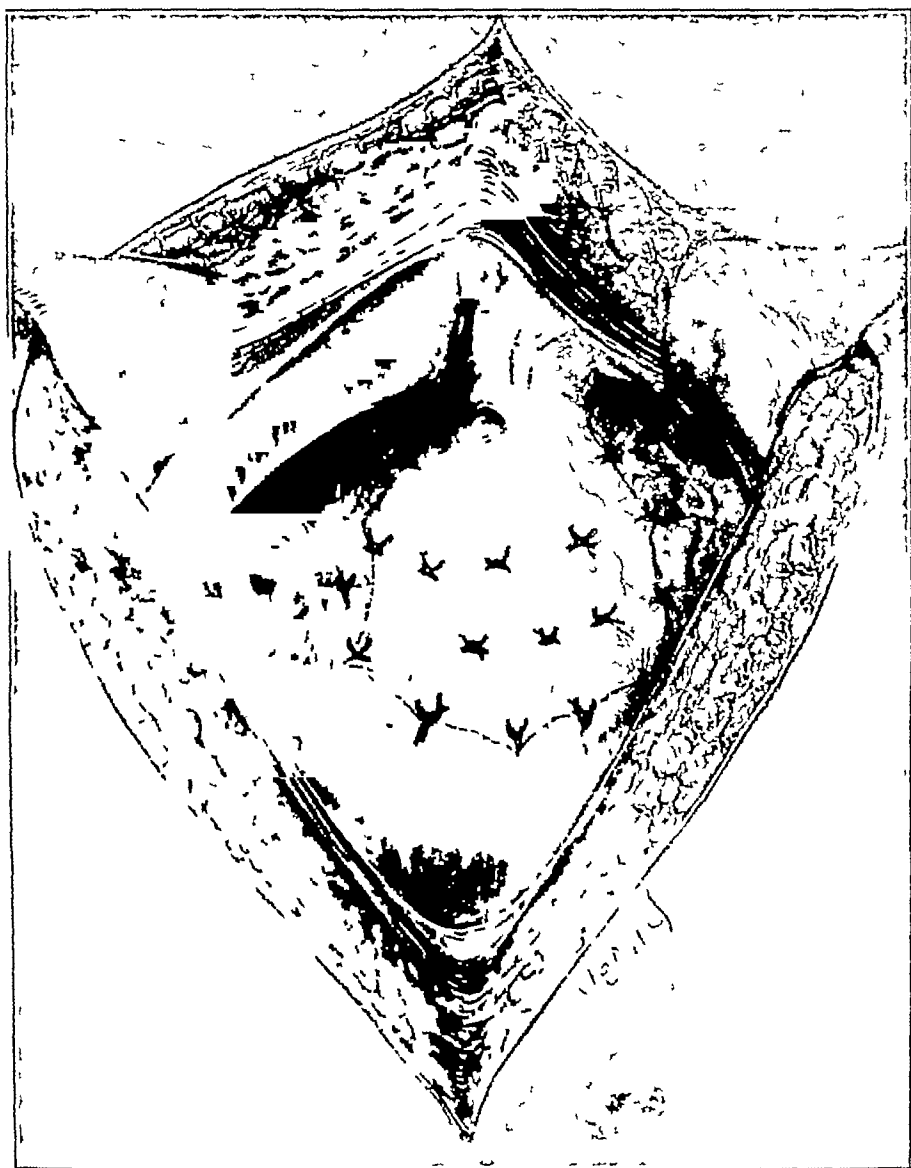


Fig 28—Crouse technic use of detached falciform and round ligaments as an addition to the Bayes operation

first part of the duodenum occurs and a shoe-fly avoidance of the obstructed third part results with a consequential rapid subsidence of duodenal toxicosis. A diseased appendix found at operation should be removed.

I shall not give case histories to exemplify the points brought out in this article, for I believe that a composite picture of many different cases of duodenal obstruction is far more elucidating and less time consuming than the citation of individual case reports

My experience in forty-nine cases has been medical in the main, as only five patients consented to some form of surgical operation

CONCLUSIONS

There is, in all probability, a chronic, pre-existing duodenal dilatation in all cases of acute gastroduodenal dilatation. The duodenum should be inspected or at least palpated the same as the gallbladder or the appendix, in all abdominal operations where such palpation does not disseminate infection.

Gallbladder, gastric and colonic operations are not complete without the inspection of the first third of the duodenum, the lifting up of the transverse colon and investigation of the retrocolonically placed duodenum as well as the duodenojejunal fold.

Duodenal dilatation is a frequent and not a rare condition.

It is cured by surgical intervention.

Duodenojejunostomy will cure most cases of duodenal ulcer.

Many patients with gastric ulcer treated by posterior, no-loop, gastro-enterostomy technic, should have a duodenojejunostomy performed as well.

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A ROENTGENOLOGIC STUDY OF THE COURSE OF POSTINFLUENZAL PYOPNEUMOTHORAX *

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During the last few months we have had the opportunity of studying roentgenologically the course of four cases of postinfluenzal pyopneumothorax, and we believe that the pathologic pictures obtained during these studies are worthy of report

These patients have all been treated as conservatively as possible and in only one case was recourse had to a radical surgical procedure

All roentgenograms were stereoscopic. They were made with a hydrogen tube, with a 33-inch target-plate distance. The patients were in the erect position and both exposures were made during one inspiration

REPORT OF CASES

CASE 1 (No 1948)—*History*—A man, J S, aged 18, entered the hospital Jan 27, 1919, complaining of severe, stabbing pain in the right chest. Two years before, he had had an attack of pleurisy which lasted five days. In November, 1918, he had sharp, stabbing, inspiratory pain in the lower right chest, and for three weeks following, a dry unproductive cough. December 25, he was tapped by his home physician and a quart of fluid, said to be bright red, was removed. One week later he was tapped with a similar result and again on January 6, 1 or 2 ounces was aspirated (Fig 1)

Examination.—February 15, he was tapped and thick purulent material was obtained. The right chest was found to be practically immobile and in front from the level of the third rib down, percussion elicited dullness to flatness with diminished to absent breath sounds. The left chest was hyperresonant with exaggerated vesicular breathing. The apex of the heart was found displaced 2 finger breadths to the left of the midclavicular line. Blood count revealed red blood corpuscles, 3,860,000, white blood corpuscles, 14,900. Differential count showed 80 per cent. polymorphonuclears. The urine was negative. The sputum was repeatedly negative for tubercle bacilli.

Clinical Course.—During January and February, the daily temperature ranged between 100 and 101.5 F. During March (Fig 2) it became normal and remained so until April 18, when he was discharged (Fig 3). He was readmitted April 24. The physical examination was essentially the same as

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at the time of his original admission except that the upper level of dulness was now at the fifth rib. The clinical course was uneventful, the temperature was normal on admission and remained so, the color was good and he gained in weight steadily until June 4. When he was discharged, his weight was equal to his previous best weight. At this time only slight dulness remained at the right base, and his general condition was excellent (Fig. 4).



Fig. 1 (Case 1)—Condition Jan. 29, 1919. Curious bands of thickened pleura, some air-containing loculi, presenting an appearance not unlike that of a diaphragmatic hernia of a gas-filled bowel.

Jan. 7, 1920, he returned for reexamination (Fig. 5). His weight remained unchanged, but he complained of rather poor appetite. Examination was entirely negative.

July 20, he again returned for examination (Fig. 6) stating that in February, he had had double pneumonia and had been in a hospital for six weeks. Since that time he had had some pain in his right chest. Six weeks before a tonsillectomy had been performed and three weeks later the submucous

membrane had been resected. His general appearance was excellent. His weight was normal. Percussion revealed slight impairment of breath sounds over the right apex in back, but the examination was negative otherwise.

Roentgen-Ray Findings—Jan 29, 1919, a roentgenogram revealed asymmetry of the thorax with emphysema on the left side. The apex of the heart was above the diaphragm in apparently normal position although the upper portion of the heart shadow and the shadow of the superior mediastinum, including the trachea, were distinctly displaced to the left, that is, away from the side in which the pathologic changes were most marked. On the right, there was



Fig 2 (Case 1)—Condition March 3, 1919. Typical straight line marking upper border of air and fluid in the pleural cavity. The pleural bands shown in Figure 1 can still be seen above the level of the fluid.

a series of air bubbles which on superficial examination suggested the presence of the large bowel in the pleural cavity. Closer examination, however, revealed the fact that there was not a complete continuity of the different cavities. The lower shadow was comparatively high, and the parietal pleura was enormously thickened. It was probably half an inch thick. There was narrowing of the interspaces, and what we believed to be the retracted lung had pathologic density which was fairly uniform and of markedly altered texture. The alternative interpretation assumed the increased density over

the liver shadow to be due to pleural exudate and the density of the lung to be due to a similar cause. Examination after ingestion of barium disclosed the fact that the shadows in the pleural cavity were not connected with the alimentary canal.

Feb 16, 1919 As compared to the preceding findings, there was a reduction in the thickness of the parietal opacity and of the shadow adjoining the posterior mediastinum. The broad bands noted previously subdividing what seemed to be the cavity of the thorax were reduced in width. The cavity was



Fig 3 (Case 1) —Condition April 18, 1919, showing the greatest extent of the effusion

more nearly continuous, and we could definitely recognize some sort of bronchovascular tree in this space. The opacity in the lower part was not quite so extensive, but was still of high degree and rather poorly defined above.

March 3, 1919 These roentgenograms revealed a horizontal fluid level in the midthorax and in the region that was clear formerly. Obviously the chest now contained both air and pus beneath a very dense, thick pleura.

April 18, 1919 The entire right side was relatively more dense than before. The fluid level could still be made out high up beneath the second rib, above which was a small air bubble.

June 27, 1919 Some retraction of the fourth and fifth interspace was noted on the right. There was pleural thickening in both apexes, particularly marked on the right and continuing practically to the diaphragm on this side. The pleural angle was obliterated on the right by a definitely demarcated area of great density, but there was an area of comparatively normal lung, mesial and inferior to the part in which the pathologic changes were noted. There was no sign of definite fluid level or air.

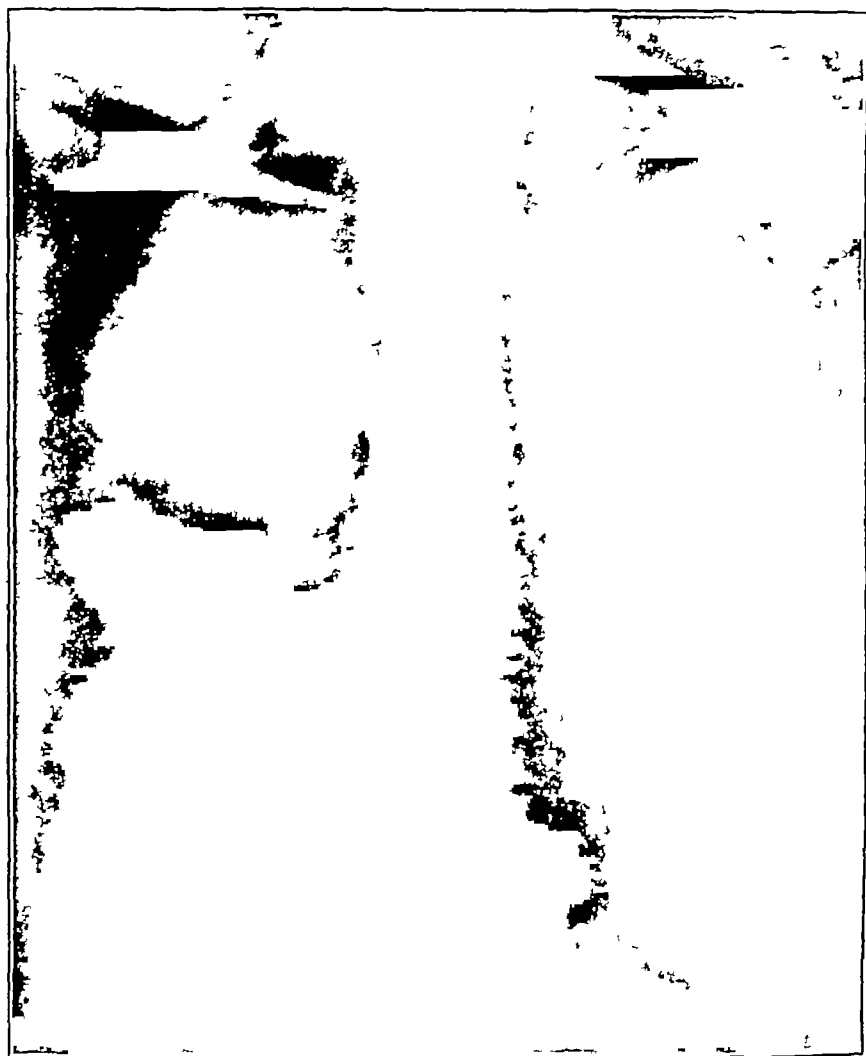


Fig 4 (Case 1)—Condition June 27, 1919 beginning encapsulation and resorption of fluid and exudate. The appearance of lung markings may be noted in the upper half of the pleural cavity.

July 8, 1920 There was an insignificant flattening on the right side above and a slight pleural line throughout the length of the axilla. On the right side, the apex was slightly obscure as though from thickening of the pleura on the anterior and posterior surfaces not seen in cross-section. All this could be easily missed.

July 21, 1920 There was definite pleural thickening at the right apex and axilla. Otherwise the chest was entirely negative.

CASE 2 (No 2010)—*History*—P D, a baggageman, white, aged 37, with a negative family and personal history, whose chief complaint was cough and weakness, entered the hospital, Jan 10, 1920. The present illness began in December, 1918, with an attack of influenza which was epidemic at that time. The patient was in bed until February, 1919. Shortly after getting up he began to cough and raise considerable greenish, foul-smelling sputum, a teacupful a day. The amount of sputum had gradually decreased, although the

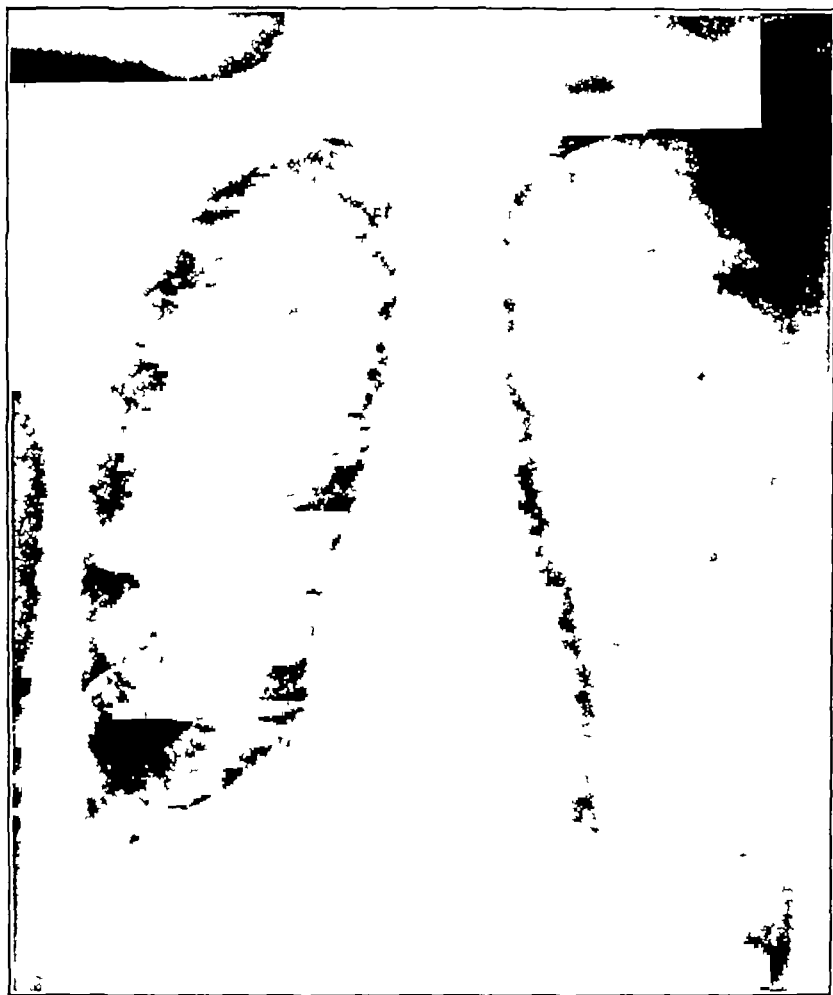


Fig 5 (Case 1)—Condition Jan 6, 1920. The only evidence of the preceding process is a fine pleural line in the axilla and slight deformity of the right diaphragm.

fetor continued. During the summer, he had paroxysms of coughing which lasted from five to ten minutes, during which he would become very faint and perspire freely.

Examination—This revealed rather poor nutrition, exaggerated excursion of the right side, and fixation on the left. The left chest showed a flattening of an area about the size of the patient's palm below the clavicle. There was slight hyperresonance on the right, with vesicular breathing, unchanged

fremitus and no râles. Slight resonance at the uppermost part of the right apex was noted. Elsewhere there was flatness. Except at the apex, no breath sounds were heard; there they were distant and metallic in character, but unchanged in quantity. On shifting the patient to the prone position, the percussion note over the back changed from flatness to dullness. Clinical findings were: hemoglobin, 85 per cent; red blood corpuscles, 4,300,000; white blood corpuscles, 13,000. The Wassermann reaction was negative. The urine was negative. The blood pressure was 120/90. The sputum was negative for tuberculosis.



Fig 6 (Case 1) —Condition July 21, 1920, after a second attack of influenza and double pneumonia, following which the patient underwent a tonsillectomy and a submucous resection. Practically no residue may be noted.

Clinical Course—The temperature fluctuated between 97 and 99 F, on one occasion reaching 100 F (Figs 7 and 8). The patient was aspirated, January 14. Cultures after diagnostic puncture demonstrated no growth. January 16, 600 cc was aspirated, January 29, 450 cc, February 16, 1,000 cc, February 25, 700 cc, which showed white cells, 33,000, and March 9, 750 cc, which

showed white cells, 30 000 White cell count rose so that on March 9 he was transferred to the surgical division for thoracotomy Smears from the fluid removed, all showed streptococci, but no growth was ever obtained

March 11, blood examination revealed hemoglobin, 85 per cent, red blood corpuscles, 4,800,000, white blood corpuscles, 16,000 Urine examination was negative March 13 a portion of the ninth rib was resected, drainage was instituted under local anesthesia and the patient made an uneventful recovery

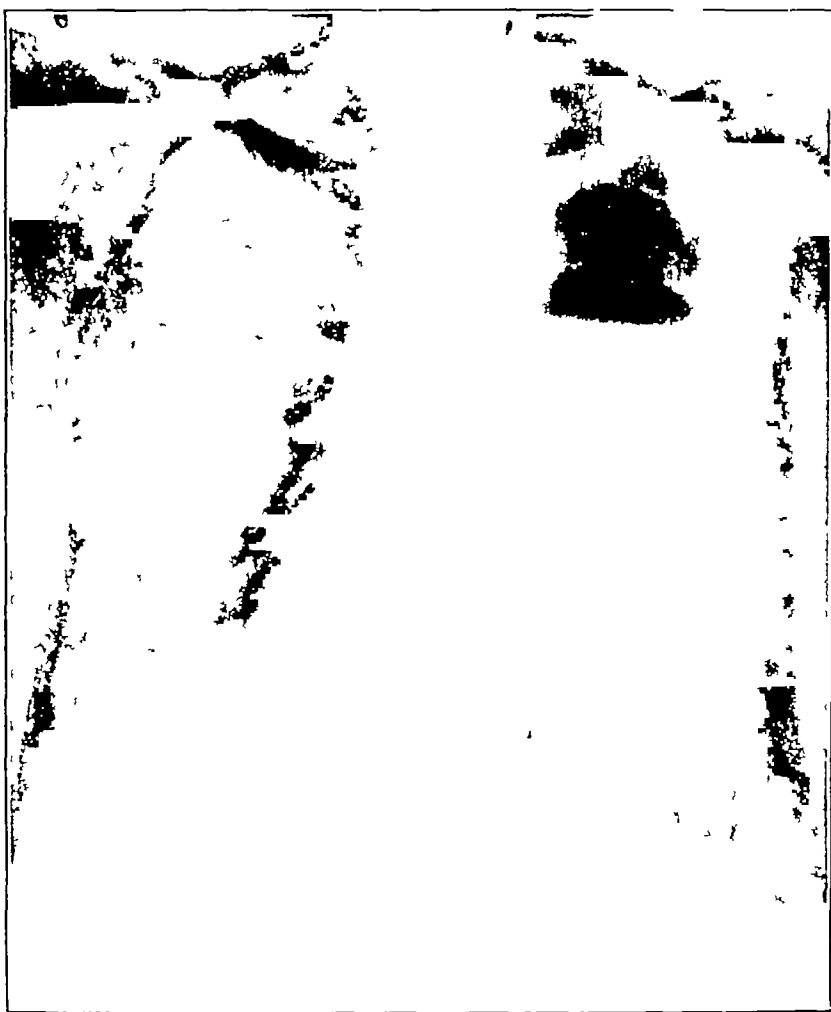


Fig 7 (Case 2)—Condition Feb 5, 1920, before aspiration

He was discharged March 22 The temperature was normal (Fig 9) July 19, the patient had gained 15 pounds and was gaining strength He felt perfectly well (Fig 10)

Röntgen-Ray Findings—Jan 10, 1920, these were pathognomonic of a fluid exudate in the left chest modified by a gas bubble The fluid exudate was separated from the lateral chest wall by an exudate one-half inch in thickness Enormous compensatory emphysema was noted on the right side

There was no displacement of the heart or mediastinum, in fact the cardiac shadow was almost entirely overshadowed and might actually have been retracted to the left

Jan 24, 1920 After aspiration, considerable density was noted in the left lower chest, which was entirely pleural in character This was found chiefly from the fifth to the eighth interspaces, and on the lateral border covering the entire left side from the first to the ninth rib There was some air on the left along the lateral border outside the lung from the fifth to the eighth



Fig 8 (Case 2) —Condition Feb 5, 1920, after aspiration expansion of lung and thickness of pleura in the axilla may be noted

interspaces The bronchovascular tree on this side was rather prominent There was no longer any definite emphysema on the right side, and the heart was normal in size, shape and position

Jan 29, 1920 After aspiration, on the left the diaphragm was still higher than normal and on this side there was a small amount of air encapsulated in the pleura though considerably less than at the previous examination The greater part of the parenchyma of the left lung contained air, distinctly more than when the previous examination was made

Feb 6, 1920 When compared to the previous roentgenograms the lung showed considerable more expansion and the thickness of the pleural exudate was considerably diminished. There was more retraction of the interspaces and the heart was displaced rather more to the right.



Fig 9 (Case 2) —Condition April 29, 1920, after operation, showing drainage tube in place. Retraction of entire left chest and thickness of pleura throughout the entire length of the axilla may be noted. Lung markings may be seen everywhere except in the extreme pleural cavity.

Feb 16, 1920 Eleven days after aspiration, two sets of roentgenograms were made before and after aspiration. The former showed a horizontal fluid level at the level of the second rib in front, with a gas bubble, apparently mostly in front. There was a small circumscribed annular shadow in the extreme apex outside a rather prominent line running down the pleura in front which was evidently an encapsulated pocket.

A stereoscopic roentgenogram taken after aspiration showed the lung partially but imperfectly expanded. The left lower lobe was distinctly thicker and denser than the one on the opposite side. The lower margin could be well made out. A curvilinear shadow along its lower border outlined a gas bubble, which, contrary to expectation, did not lie in the upper portion of the thorax, but immediately above the diaphragm. Marked thickening of both the visceral and parietal pleurae was noted in the middle third of the chest. The encapsulated annular shadow in the apex remained as before. Narrowing of the thorax on this side and displacement of the trachea persisted. As

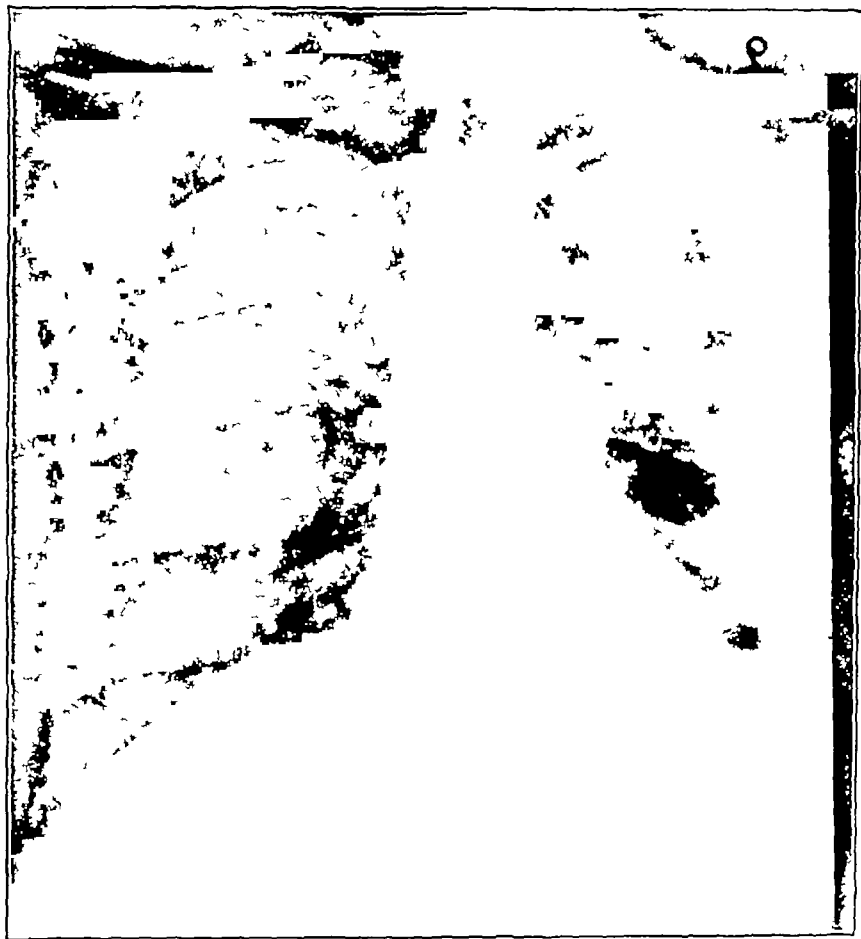


Fig 10 (Case 2) —Condition July 20, 1920 although there is marked contraction of the left chest, the lung on the affected side is functioning. The patient has regained his normal weight.

a whole, the lung, which was now expanded, was denser than the one on the opposite side. Evidently these differences in density were due to blood.

Feb 25, 1920. The roentgenograms were practically identical with the preceding.

March 10, 1920. The line representing the thickened interlobar pleura was not at all marked in these roentgenograms as compared to the previous ones. The lung was much better distended and extended laterally to within an inch and a half of the pleural margin.

April 30 1920 After thoracotomy roentgenograms showed adequate drainage. The pleural thickening persisted.

May 28 1920 The lung itself was less dense than previously. There was marked retraction of the entire left chest. Pleural thickening was seen laterally from the apex to the base, but less marked than before.

June 22 1920 The lung was well expanded but the broncho-vascular tree was especially clear. The pleura was definitely less dense, and the pleural angle was very much more free than at the previous examination.



Fig. 11 (Case 3)—Condition April 11 1920 sharply circumscribed upper border and lung markings may be seen through the air in the pyopneumothorax.

July 20, 1920 Very little change from the previous examination was noted.

CASE 3—History—C. W., white, man, physician, aged 35, during the influenza epidemic had all the symptoms of a typical attack in February, 1920, but apparently recovered. He had a second attack two weeks later.

Clinical Course—After three or four days, marked cyanosis, dyspnea and leukocytosis were noted. He complained of pain in the right lower chest. Examination disclosed no signs of consolidation. At no time were there signs of consolidation. After three days, there was dullness in the middle of the right back in the scapular region. This rapidly became more marked and

spread down until the right back from the fourth rib to the diaphragm showed marked dulness to flatness with diminished to absent breath sounds and fremitus. There were no signs of displacement of the heart.

Dull tympany, increased fremitus and bronchovesicular breathing were detected at the top of dulness. On paracentesis, no fluid was obtained.

The temperature dropped about 2 degrees, the patient's general condition became better and it was believed that the pneumonia was beginning to resolve (Fig 11).

All signs, however, remained as described, leukocytosis, temperature varying between normal and 102 F, persistent pain in the chest and dyspnea, and limitation of motion of right chest. Paracentesis revealed thick pus. The signs remained practically the same from then until an operation was performed on April 15, 1920. There was never any displacement of the organs. Following the operation the temperature became normal and has remained so since.

The patient has now regained his normal weight and is doing heavy outdoor work without dyspnea or discomfort (Fig 12).

Roentgen-Ray Findings—The pathologic changes were confined to the lower part of the right chest. A uniform shadow extended from the spinal shadows of the chest wall, sharply limited above in a horizontal line and impinging laterally on another line evidently representing thickened pleura. The degree of density was not very great, in fact some lung texture could still be made out through the most dense part of this shadow. The pleural angle was obliterated and the diaphragm was elevated. Above this horizontal fluid line was a smaller area circumscribed by an indefinite curvilinear line which followed the posterior chest wall. It was continuous with the shadow in the axilla, and we believe the whole represented a circumscribed cavity containing both pus and air. The left lung showed smaller areas of exaggerated reticulum both centrally and peripherally, evidently a residue of previous pneumonic involvement. There was beginning retraction of the interspaces on the right side, below. The displacement of the heart, which was not marked, was toward rather than away from the side presenting the most marked pathologic change.

March 16, 1920. There was no change.

March 23, 1920. Very slight diminution in the amount of fluid was noted, otherwise the roentgenogram was identical with the first one.

April 12, 1920. Density of the lower part was increased and the line limiting the air bubble above was denser. There was distinct thickening of the pleura laterally.

May 14, 1920. The roentgenogram showed the drainage tube in place. There was comparatively little pleural thickening though there was a definite double pleural line extending from the base to the apex. The opposite side showed a fine pleural line over the apex. The entire cavity, which had a rather thick wall, had shrunk until it was about twice the size of a hickory nut. The limiting membrane was only slightly more vascular than the rest of the lung. It was not completely consolidated and was not sharply delimited.

July 26, 1920. The right diaphragmatic angle was somewhat obscured and hazy. The bronchovascular tree in this region was of the finely reticulated type and that in the lower half of the lung was distinctly more marked. With the exception of the slight fibrosis and pleural thickening at the right base, the lung had returned to normal. The residual changes would easily be overlooked on casual examination.

CASE 4 (No 241) —E P entered the hospital January 26, complaining of weakness and general malaise. His symptoms and signs were those associated with typical influenza.

Clinical Course —Shortly after admission, he had a chill and the temperature rose to 102 F. On the following day there were signs of consolidation throughout the entire lower left lobe with a patchy involvement of the middle lung field. On the 31st, he complained of pain in the left side on breathing,

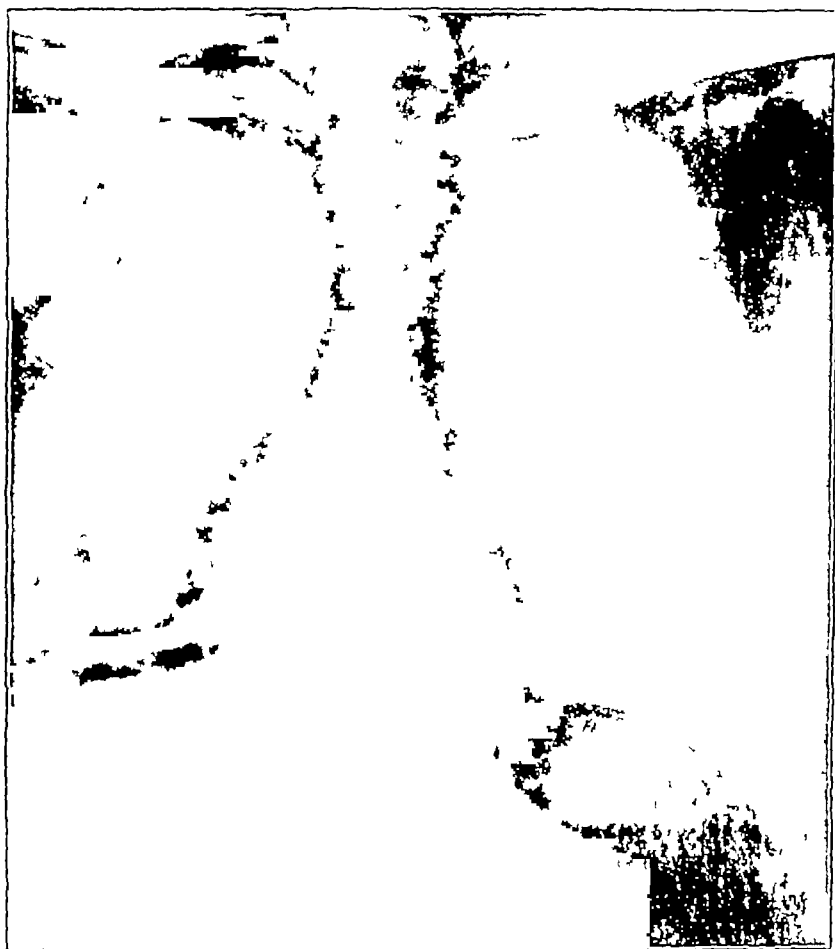


Fig 12 (Case 3) —Condition July 26, 1920 except for the haziness in the lower part of the right chest, no residual changes are demonstrable. Patient has regained normal weight and is able to do heavy outdoor work.

a friction rub was heard and the side was strapped. February 1, he was extremely cyanotic, the respirations were rapid, and the pulse was of poor quality, varying in rate between 130 and 150. The white count at this time was 10,000. From the 1st until the 8th, the temperature fluctuated daily between 99.5 and 103 F. February 11, 2,300 cc of thin greenish pus was removed from the left chest, and from this fluid a hemolytic streptococcus was isolated. On the 17th, and again on the 26th, the chest was tapped and similar fluid obtained. On the 26th, air was demonstrated on aspiration.

Until February 26th, the daily maximum afternoon temperature was about 102 F. Following the tapping, the maximum temperature was 99.5 until March 5, when it again rose to 103. On the 7th, 1,000 cc of purulent fluid was removed from the left chest. The fluid on this occasion was considerably thicker than that obtained on previous aspirations. On March 9, he was transferred to the surgical department and on March 12, under local anesthesia, a rib resection was performed and two drainage tubes were inserted. Following this the patient made an uneventful recovery.

Röntgen-Ray Findings — Feb 25, 1920. The lower portion of the left thorax was filled with a uniformly dense shadow with an approximately horizontal upper level above which was a space free from any detail which evidently contained air. This air space was limited above by a curvilinear line reaching from the third rib in the axilla to the middle of the hilus, and



Fig 13 (Case 5) —Condition March 1, 1920. unusual picture of the collapse of a consolidated lung. Without consolidation this lung might not be seen beyond the shadow of the sternum and spine.

below by a broadly curved line evidently representing some portion of the heart. The upper lobe on the left showed a great thickening along its base. This was evidently due to interlobar thickening. The texture of this lung was exaggerated. The reticulum was marked and a few localized opacities were noted peripherally. The right side of the thorax showed some indefinite localized increase in the bronchovascular tree suggestive of a past influenza. The cardiac shadow was much displaced. The apex seemed to be on the right side, but a fine differentiation in this region was not possible.

March 7, 1920. The findings were almost like the preceding except that the amount of fluid was less than before, and the appearance of the left upper lung had lost all features suggestive of tuberculosis. The retraction of the interspaces was distinctly more marked and the thickness of the pleura had increased.

CASE 5 (No 5103) —*History*—R. R., aged 2, girl, entered the hospital February 5, as an emergency case of influenza.

Examination—This revealed signs of consolidation at the base of the right lung

Clinical Course—The patient improved until February 25, when signs of fluid on the left were discovered. At that time, the right chest was practically free from physical signs. Thoracentesis yielded a seropurulent fluid. The patient was again aspirated on the 29th. The patient struggled during this procedure and only about 1 cc of fluid was obtained. After this a small amount of subcutaneous emphysema developed (Fig 13). On March 4, signs of air and fluid were obtained on the left. The heart was displaced to the right. The patient died during an attempt to aspirate the chest.

Necropsy—This revealed a left pyopneumothorax with complete collapse of the lung which was covered by an exudate one eighth inch thick.

Roentgen-Ray Findings—Feb 26, 1920, abnormal opacity in the left lower lobe mostly behind and reaching to the seventh rib was noted. This opacity was diffuse, showing imperfectly the exaggerated reticulum with the density near the center completely obscuring the costophrenic angle. It did not rise characteristically in the axilla. There was no retraction of the interspaces or displacement of the heart or mediastinum. There was a distinct shadow corresponding in shape and position to a thymus of considerable size.

March 2, 1920. An unusual picture of an intensely opaque collapsed lung lying free in an air-containing pleural cavity was presented. The outlines of this lung were those of the expanded lung and there was evidently consolidation of both lobes on the left side. In addition there was a pneumothorax without demonstrable fluid in this position (roentgenograms were taken with the patient in the prone position). There was some displacement of the mediastinal contents but this was not very marked. The thymus shadow at this time was not very conspicuous. The border of the heart was entirely lost in the shadow of the lung.

COMMENT

These cases present almost all the conceivable findings in such a process. The first two cases are of interest because of the long duration of the empyema. Case 1 shows the strong tendency on the part of these patients to recover spontaneously. The treatment consisted only of rest in bed and relatively few aspirations. Cases 2 and 3 show also the tendency toward spontaneous recovery but in these cases improvement became stationary under expectant treatment. Both of these patients recovered, and the physical roentgenographic findings revealed rapid improvement after a simple thoracotomy and a tubular drainage. In Case 4 the patient recovered clinically after rib resection and drainage. Case 5 shows the importance of position in making the diagnosis of air and fluid by roentgen-ray examination and is perhaps added evidence in support of the proposition that in this form of bronchopneumonia it is not necessary to consider the empyema (unless it becomes so massive as to cause mechanical difficulty) until the acute process has subsided.

In two cases (1 and 3) the condition of the chest at the present time is practically indistinguishable from that of the normal. It is

not possible to say how much deformity will eventually remain in Case 2 but judging from the others a great deal of the pleural thickening should disappear. Unfortunately, we have no recent roentgenogram of Case 4 but clinically the deformity is not great.

It would, therefore, appear that expectant treatment with aspiration when indicated was justified in these cases until improvement was no longer clinically demonstrable. At this time, the indication is for the simplest surgical procedure that will supply adequate drainage.

We present these cases and roentgenograms to demonstrate how completely the normal chest markings may be restored even after the presence of extensive adhesions, marked pleural thickening and pulmonary deformity. In treating cases of this type, it should be remembered that during the acute stage the effusion should not be removed, unless there are definite indications. We believe that the procedures which are subsequently employed should be as conservative as possible. The indications for the employment of these should be determined by the clinical course and by frequent roentgen-ray examinations.

THE RÔLE OF THE CORTICAL LYMPHATICS IN THE EXTENSION OF TUBERCULOSIS WITHIN THE KIDNEY

E GRANVILLE CRABTREE, MD

BOSTON

Clinical experience has established the futility of partial nephrectomy as a surgical measure in cases in which the lesion of the kidney is tuberculous. The purpose of this communication is to contribute further pathologic evidence as to the paths of extension of tuberculosis within the kidney, in justification of operations now employed, rather than to discuss what is already established as a sound surgical procedure.

The observations here recorded were made on a group of twenty-one kidneys, obtained at operation, which showed macroscopically a single small lesion at some point in the renal substance with an attendant tuberculous pyelitis. In some instances, the cortex was almost, if not entirely, free from gross lesions, yet in most instances there were a few small cortical tubercles to be seen overlying the gross lesion of the interior of the kidney and connected with it by lines of tuberculous infiltration. There was in each instance a considerable portion of the kidney cortex which seemed grossly to be normal. To these apparently uninvolved portions of the cortex my study was directed with the purpose of demonstrating new lesions, if any were present, which might be concerned in the subsequent destruction of the kidney. These early cases are not common. The twenty-one kidneys studied have been collected from the surgical services at the Massachusetts General Hospital and from private practice.

The studies of Ekehorn¹ have thrown much light on the manner in which a tuberculous focus in the kidney spreads in the pelvis of that kidney. It is generally recognized that a primary tuberculous focus in the kidney is almost invariably situated in the region of the medullary portion of the kidney cortex at the base of the pyramid in the region of the loops of Henle. That these may exist for a time without symptoms seems to be a clinical fact. Eventually the process extends in all directions and breaks by the shortest path spontaneously into the pelvis which is nearer than the cortical surface. After the tuberculous process has ruptured into the pelvis, a tuberculous pyelitis with its attendant symptoms soon develops. Ekehorn

¹ Ekehorn. Die Ausbreitungsweise der Nierentuberkulose in der tuberkulösen Niere, *Folia Urolog* 2 412, 1908

has demonstrated by serial sections of all the pyramids of such a kidney, that all the pyramids rapidly become infected. Tubercle bacilli are found in greatest numbers in the recesses of calices where urinary drainage is probably less complete, and the pyramids soon become involved in these regions. From these lesions, he believes ascending infection takes place within the kidney along the lumens of partially obstructed tubules and by way of the intertubular lymphatics and perhaps by the blood vessels.

The presence of tuberculous pyelitis is, in itself, sufficient evidence to justify the complete removal of a tuberculous kidney no matter



Fig 1—Microscopic section, $\times 50$, from the apparently normal portions of a kidney in the opposite pole of which there is a small active tuberculous focus. Note that the tubercle apparently takes origin from the interstitial tissue and not from glomeruli. Aside from the row of cortical tubercles, two of which are shown here, the tissue of this pole of the kidneys shows no tuberculous changes. There is tuberculosis of the pelvis throughout all its parts. (Photomicrograph by L. S. Brown.)

how small the amount of renal tissue destruction which may have taken place. There is, however, a small group of cases in which there is a double kidney with separate pelves, only one of which is infected, another group in which there are fused kidneys, and more rarely a group in which there are normally developed kidneys in which a small chronic lesion of one pole has resulted in the formation of a sclero-

caseous partition which separates that portion of the pelvis from the remainder. In these cases the temptation to perform a partial nephrectomy is great. I have one double kidney in my series of twenty-one, only one pelvis of which shows a tuberculous pyelitis, yet the outlying cortical tissue of the portion connected with an uninvolved pelvis shows microscopic tubercles.

I have repeated the work of Ekehorn and believe that it represents the facts. Yet in many instances, I find in apparently normal portions of the cortex, remote from the region of the primary focus, numerous

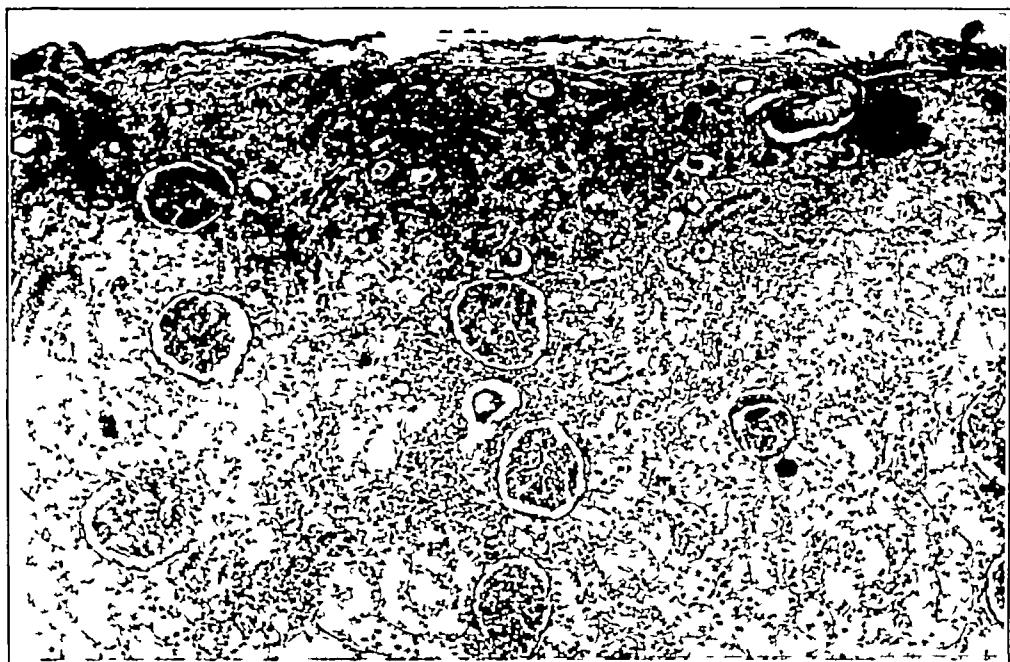


Fig 2—A small area of diffuse tuberculous infiltration, $\times 70$, just beneath the capsule in a portion of a kidney macroscopically normal. There is a small focus of active tuberculosis in the opposite pole from where this section was taken. Note that the glomeruli are not involved. Tubercle bacilli were found in the region of the giant cells near the central portion of the area. (Photomicrograph by L. S. Brown.)

microscopic tubercles just beneath the true capsule which seem not to be connected with the pelvis by the usual fine lines of round cell and endothelial cell infiltration which is usually found where there is extension to the cortex from an underlying caseating cavity. Also in the one double kidney there was no demonstrable process in the pelvis or medullary portions of the other half, yet the cortex showed numerous small tubercles beneath the capsule. I believe that these lesions are due to lateral extension by way of the cortical lymphatics.

Kumita,² Sakata³ and Sugimura⁴ have demonstrated in the fatty capsule of the kidney two intercommunicating plexus of lymph channels which in turn connect with a lymph plexus just beneath the true capsule. Lymph channels from the parenchyma drain into the lymph plexus just beneath the true capsule and from that may communicate with those of the fatty capsule. Undoubtedly the intertubular lymph spaces play an important part in spreading infection between pelvis and cortex. With these spaces invaded, infection of the greater lymph spaces of the cortex is easily accomplished. By this means tubercle bacilli may be distributed along the cortex to portions of the kidney remote from the primary lesion, but since the lymph channels of the separate portions of a double kidney and of fused kidneys intercommunicate, cortical invasion of the second kidney may also be expected.

I am unable to offer an opinion as to how great a part these microscopic tubercles play in accomplishing the destruction of the kidney. The small cortical tubercle, indeed, is often found sclerosed. Yet I am not prepared to deny that secondary tubercles may not develop deeper in the kidney tissue from these cortical tubercles, and these secondary lesions be of considerable significance in accomplishing the destruction of the kidney. In one or two instances, I have found beginning tubercles containing bacilli a short distance down in the kidney substance directly beneath the cortical tubercle, situated in a medullary ray and connected with the tubercle by lines of tuberculous infiltration. The fact that the small cortical lesions actually do contain tubercle bacilli, that they may be found in portions of the kidney that are macroscopically normal, and that they may even extend across the line of division between the halves of a double kidney, seems to me to indicate an origin separate from the process in the pelvis.⁵

2 Kumita. Ueber die Lymphgefäße der Nieren- und Nebennierenkapsel, Arch f Anat u Entwicklungsgesch, 49-58, 1909

3 Sakata, K. Ueber den Lymphapparat des Harnleiters, Arch f Anat u Entwicklungsgesch, 1, 1903

4 Sugimura, S. Ueber die Beteiligung der Ureteren an der akuten Blasenentzündung usw, Virchow's Arch f Path Anat 206 20, 1911

5 The contents of this paper are embodied in the section on "The Pathology of Renal Tuberculosis" in Cabot's System of Urology

ABDOMINAL INCISIONS *

E P QUAIN, M D

BISMARCK, N D

One of the important problems confronting the conscientious surgeon is that of gaining access to deep seated pathologic conditions in such a manner that the patient may suffer the least possible post-operative anatomic damage. It is true that our first duty is to save or prolong life, and to cure disease. But if in our efforts to accomplish these laudable things we leave the patient with a new pathologic condition of an equal or even more disabling character than the disease itself, then the surgical treatment was ill-advised or ill-managed, and the cause of surgery will suffer because of the fact that the patient continues to suffer.

A number of lesions amenable to surgical treatment are amenable only through the infliction of serious and permanent anatomic damage. This is often the case in the surgery of cancer and in various infections which threaten the patient's life or limb. In such instances, it would be a serious mistake not to act bravely even when mutilation is necessary. But the great majority of the surgical operations performed today are more or less of an elective type, and of such a nature that knowledge of anatomy and good technic should reduce to a minimum all unpleasant postoperative symptoms. In this class of surgical lesions we must in a certain sense reverse the rule we follow in radical cancer surgery, and we should say to ourselves, first, "We shall do no harm," and second, "We shall cure the disease."

The incision through the anterior abdominal wall in elective laparotomies demands considerable forethought with certain definite aims if we are to live up to our first dictum. We must have in mind these anatomic facts. The main body and strength of the abdominal wall is made up of three lateral, flat and superimposed muscles, the external and internal oblique and the transversalis. These muscles take origin from the ribs, lumbar and iliac bones, and end in one broad tendon or aponeurosis which unites at the midline with its fellow of the opposite side (Figs 1 and 2). This tendon is split vertically on each side of the midline to form a canal within which lies the practically sheathless rectus muscle. At the outer margin of this canal is the semilunar line

* Read before the Montana State Medical Society, Helena, Mont, July 14, 1920

or conjoined tendon of the lateral muscles. It is important to recognize this landmark in all lateral incisions into the abdomen. The function of the three lateral muscles is to pull outward and backward from the midline in front and thus to produce a narrowing of the abdominal cavity and an increase in intra-abdominal pressure. Contraction of the rectus muscle in front tends to shorten the abdominal cavity by approximating the ensiform cartilage to the pubes. It has but loose fibrous connections with the aponeurotic tube within which

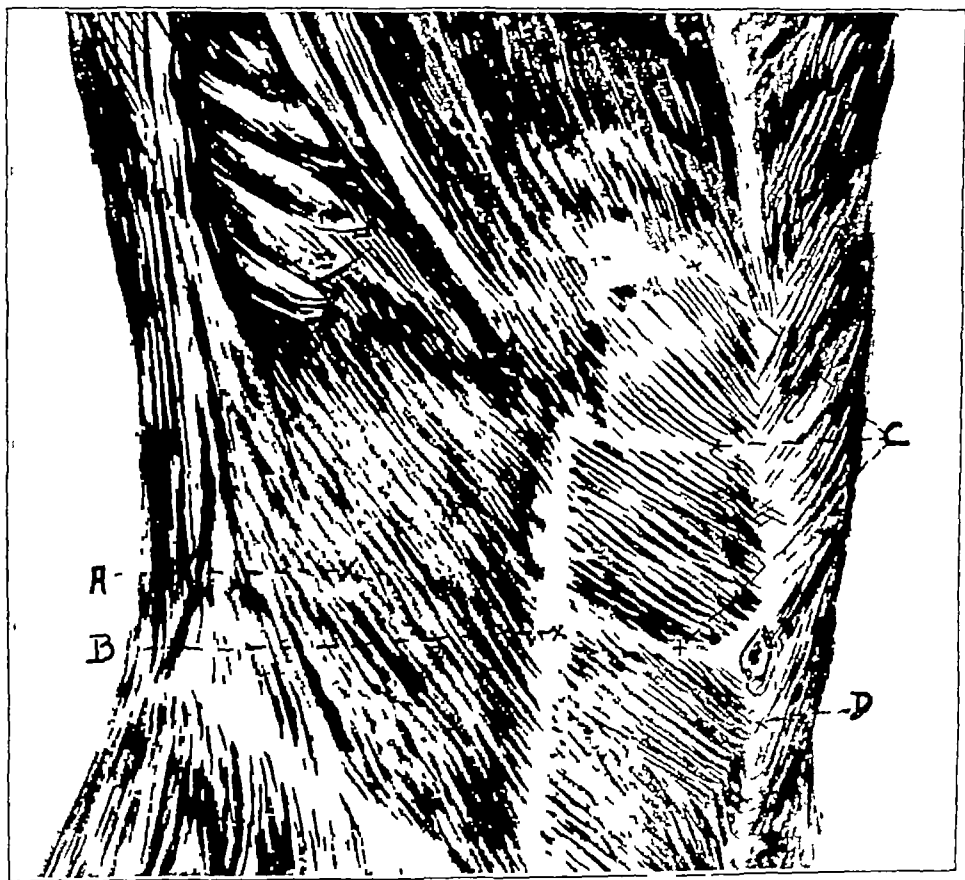


Fig 1—Outer layer of muscles and aponeuroses of anterior abdominal wall
A, external oblique, *B*, linea semilunaris, *C*, lineae transversae, and *D*, linea alba

it lies and can therefore retract an appreciable distance when cut across, especially in its lower half. Under the muscles lies the transversalis fascia. The fibers of this structure also run transversely and parallel to the transversalis muscle and carry with them in close association the peritoneal blood and nerve supply. The peritoneum is more closely attached to the transversalis fascia above the umbilicus than below.

The blood supply is derived from the intercostal arteries outside the semilunar lines and from the deep epigastrics between the two semilunar lines (Fig 3)

The nerve supply to the abdominal wall so far as known is derived entirely from the intercostal nerves, usually from the sixth to the twelfth. These nerves control the functions of the muscles and carry sensations from the skin and peritoneum. They have the same trophic relationship to the structures of the abdominal wall that the brachial plexus has to those of the hand. The intercostal nerves enter the abdominal wall at the costal border, between the internal oblique and transversalis muscles. From this region is given off a very fine network of nerve filaments which pass mesially to supply the peritoneum. The coarser and visible nerve fibers, running more or less parallel to the muscle fibers and aponeuroses, end in these structures and in the overlying areolar tissue and skin. The motor nerves leading to the rectus muscle pass underneath the outer margin of this muscle and

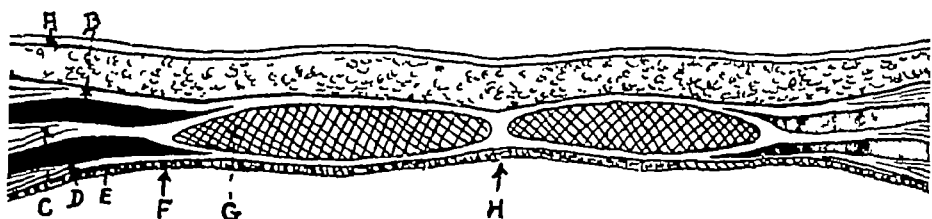


Fig 2—Transverse section of abdominal wall below umbilicus. *A*, skin, *B*, external oblique, *C*, internal oblique, *D*, transversalis muscle, *E*, transversalis fascia and peritoneum, *F* opposite semilunar line, *G*, rectus muscle, and *H*, linea alba.

enter it along its central line near the deep epigastric artery (Fig 4). From this line, the nerve filaments are distributed both outward and inward to supply the rectus muscle.

Keeping these anatomic relations in mind, it is evident that whenever an abdominal incision is made vertically, that is, parallel to the long axis of the body, the structures which give the chief support and tone to the abdominal wall are being cut across. A vertical incision in the median line, while it temporarily loosens the insertions of the lateral tendons, can fairly easily be restored almost to normal. But if the vertical incision be made to the side of the midline, as is the case in the transrectal or pararectal incisions, then an anatomic injury has been inflicted which in all likelihood cannot be restored to normal. The fibers in the aponeuroses, that is, the tendons of the lateral muscle bundles, are severed, and while it is true that they may be resutured and made to heal, it is also true that very often they do not heal firmly

enough to withstand the intra-abdominal pressure. The cut fibers are pulled away from the wound by the lateral muscles, making proper peritoneal closure very difficult, as all those know who have seen the catgut tear out between the fibers while they were trying to close vertical incisions on patients just recovering from deep anesthesia. Pannett¹ found experimentally that any irritation of peritoneum or viscera produced an active spasm of the lateral muscles. This spasm may continue for some time after the operation, and the usual plain catgut closure is not enough to insure against a later separation of tissues.

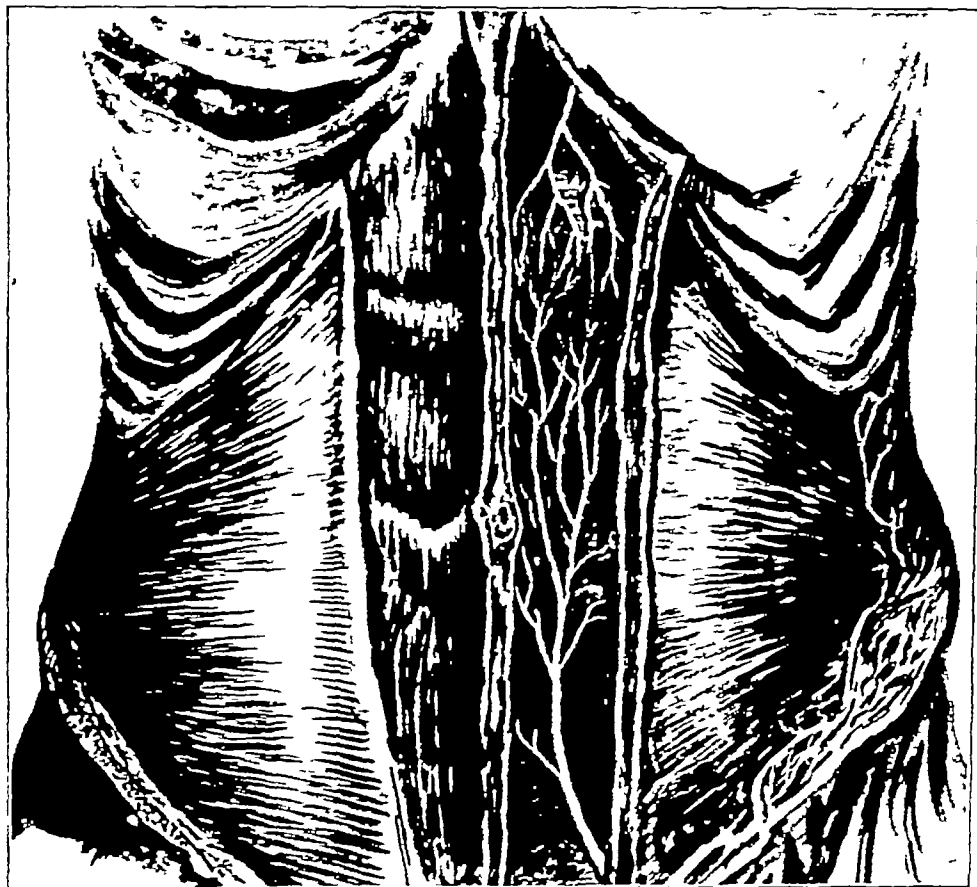


Fig 3 — Left rectus removed showing distribution and anastomosis of internal mammary and deep epigastric arteries

When it becomes necessary to leave drainage because of infection in any vertical wound there is a permanent gap between the fibers and postoperative hernia and other troubles are always invited. After drainage has been left in situ for a few days, the ends of the fibers become fixed in their retracted position by new tissue, and there is no physiologic force tending to re-approximate them—quite the contrary.

1 Pannett C. A. Surg. Gynec. & Obst. 30:408 (April) 1920

Another serious injury inflicted by the lateral longitudinal incision is the destruction of the intercostal nerve supply to the structures between the incision and the midline, or *linea alba*. This has been found in many cases to be of greater significance than the harm described in the aponeurosis. If two or more intercostal nerves are cut, the paralysis in their segment of the rectus muscle becomes permanent. The muscle atrophies, and becomes fibrous. Unless strong aponeuroses are present which heal very firmly after the operation, and unless the patient exercises special care in the use of the abdominal muscles after operation, there is likely to be more or less bulging at



Fig 4—Segment of right rectus removed, showing intercostal nerves entering rectus muscle along its posterior central line

this part of the abdomen a few weeks, or months, later. It is possible to incise the aponeurosis behind the rectus and preserve the visible nerve fibers running across the line of incision. This may save the rectus muscle, but it does not save the peritoneum for its nerve supply originates from the intercostal nerves at the costal margin, and the filaments follow the transversalis fascia as a delicate network, imperceptible to the naked eye. Severing the peritoneum thus from its nerves removes the trophic influence required for the maintenance of normal physiology. If the enervated section of peritoneum has been bruised or mildly infected during the operation, it is less able to endo-

thelialize properly and to overcome infection than is the normal serosa. The result is that permanent adhesions of omentum or other organs are often found over part or all of the enervated area. At one time I² proved this clinical observation in a series of animal experiments. In these experiments it was found that a section of peritoneum deprived of its intercostal nerve supply is unable to overcome an amount of trauma or infection which a normally functioning peritoneum would take care of, and leave no permanent evidence of damage.

AUTHOR'S METHODS

In order that the incision itself might leave the least possible pathologic residue and at the same time be well placed, ample, and offer the most satisfactory line of drainage, for several years my associates and I have used the methods here described.

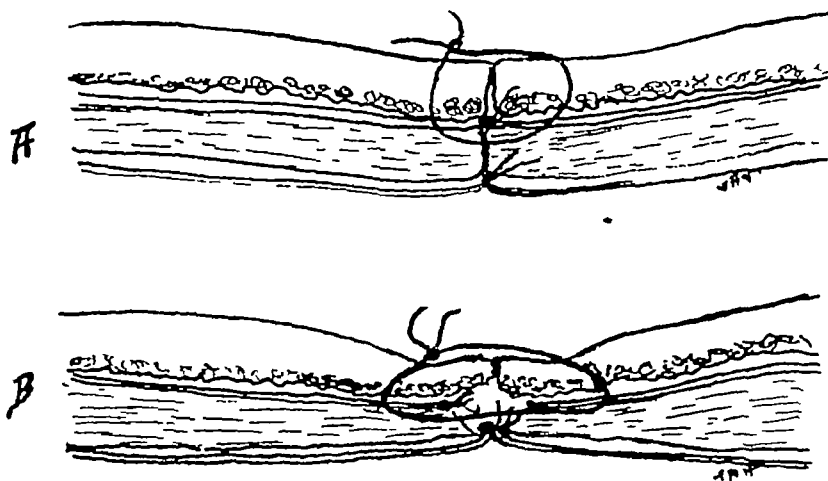


Fig 5—*A*, side-to-side silk worm gut fixation sutures, *B*, inefficiency of this suture to hold edges of aponeuroses together against lateral muscle strain.

The median incision is the routine in most pelvic operations. The Pfannenstiel or transverse incision is sometimes preferred when the round ligaments of the uterus require surgical intervention. It is of special advantage in the presence of a very fat or short abdomen. When it is known beforehand that infectious accumulations in the pelvis will require drainage after operation, it has been found wise to establish vaginal drainage through the culdesac before the abdominal incision is made. This will often obviate all soiling of the wound from a sudden gush upward when the abscess cavity bursts open.

In closing the median incision, special care must be given to the approximation of the deep aponeurosis at Douglas' fold. Several

hernias have been seen because this point had been overlooked. The two recti should be sutured together to reinforce the linea alba. The anterior aponeurosis will heal most surely if the margins are overlapped one-fourth or one-half inch. Edge-to-edge approximation is not enough. Softening of the catgut and straining of the muscles favor separation from the moment the operation is completed. The side-to-side silkworm gut sutures, usually depended on for fixation of the wound during the healing process, do not hold the wound firmly together unless they are tied so tightly that they cause injurious pressure on the tissues (Fig 5). A more effective method, and a method

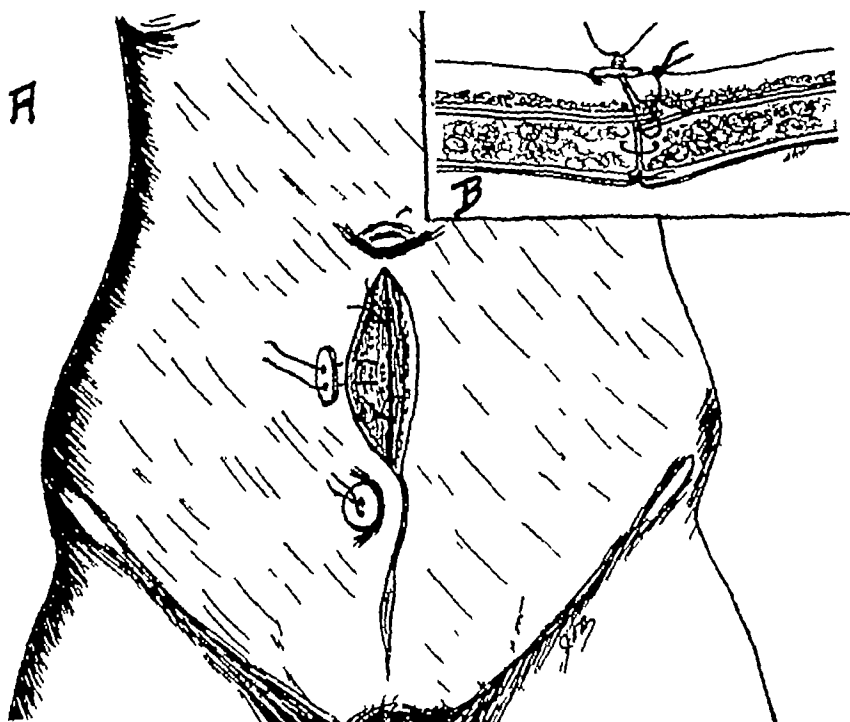


Fig 6 — *A*, closure of median incision, showing overlapping of anterior aponeurosis and position of silkworm gut fixation sutures. *B*, cross-section of closed wound.

less constricting to tissues, is the introduction of a silkworm gut through the overlap of the aponeuroses in a short bite only, the two ends of the suture coming out closely together, well to the side of the wound, and being tied over a suitable button. The two aponeurotic surfaces coming in contact should be free from all intervening tissue, but for the purpose of insuring immediate blood supply to the margins of the aponeuroses it is advisable not to loosen the undersurface of the under flap from the rectus muscle, nor the upper surface of the upper flap from the fat and subcutaneous tissues (Fig 6).

The appendix and the lower ureter are accessible in most cases through the so-called "split muscle" incision, placed somewhat below McBurney's point. The fibers of the external oblique should be split far enough both up and down to permit easy retraction of the slit in the two deeper muscles and in the transversalis fascia. The situation of the motor nerves for the inguinal region, just inside the anterior superior spine, must be remembered whenever the transversalis fascia is split far outward.

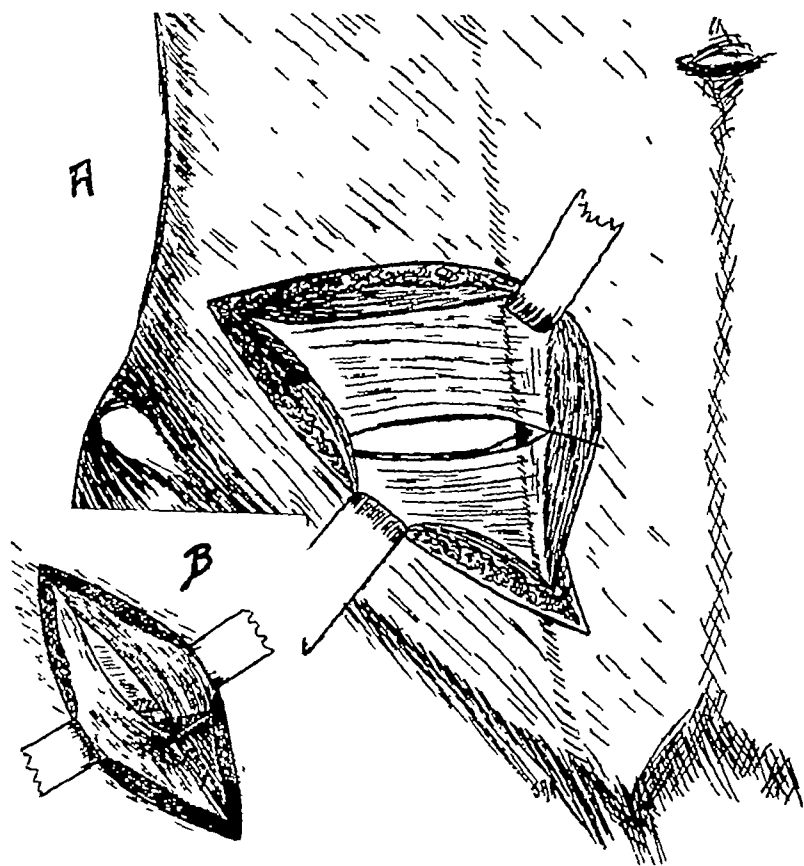


Fig 7—A, split muscle incision extended across semilunar line B, closure of incision

When pus is expected to escape through the wound, care should be exercised that the space between the external and the internal oblique be not opened farther than absolutely necessary. The infection will burrow as far as this space is opened, and it may go farther.

If the strictly "split muscle" incision is found to be too small, it can easily be enlarged by cutting across the semilunar line and separating the fibers of the aponeurosis over the rectus and retracting the rectus (Fig 7). If more space is required, the rectus muscle will suffer no harm from being cut across and later resutured. If the original oblique incision was not too high and the wound is thus

enlarged mesially, the right half of the pelvis is easily accessible to the operator. Should the tip of an abnormally situated appendix be adherent high outside or behind the ascending colon and therefore inaccessible through the low opening described, it can nearly always be reached by extending the incision between the external oblique fibers outward and making a second splitting through the deeper muscles and the peritoneum (Fig 8). To increase the accessibility in this manner by means of a second peritoneal opening is a much less destructive procedure than to yield to the temptation of enlarging the original wound by cutting across the lateral muscles and the transversalis fascia with the intercostal nerve fibers.

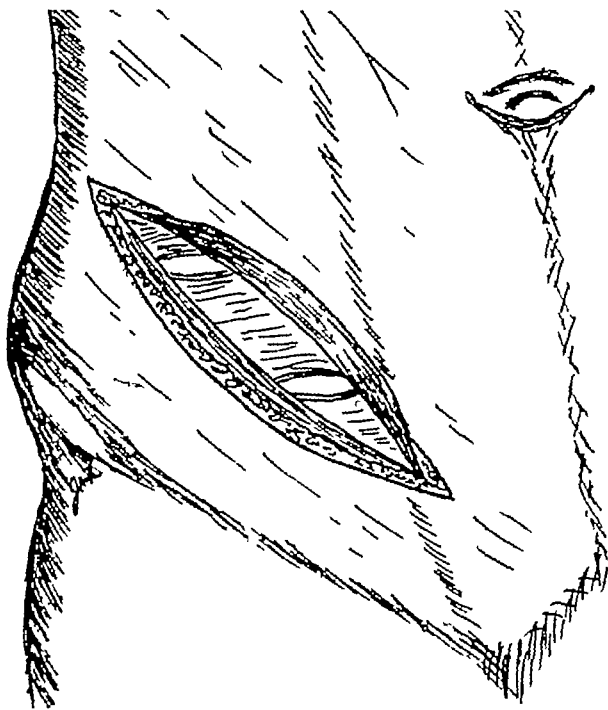


Fig 8—Secondary splitting of internal oblique and transversalis muscles at a higher level, to expose upper part of rectocolic space (usually made much higher than indicated here)

In the upper abdomen, the most important organs requiring surgical treatment are the biliary apparatus and the stomach. Our preference in stomach surgery and our routine in operations on the gallbladder and ducts, is the straight transverse incision, made about 2 inches above the level of the umbilicus (Fig 9). The incision is carried down through the aponeurosis from a point near the linea alba and outward to, or beyond, the linea semilunaris. Only the outer fibers of the rectus muscle are cut at first. The posterior aponeurosis near the semilunar line is exposed and split. The transversalis muscle and fascia with the attached peritoneum is opened sufficiently to admit

one or two fingers for preliminary exploration. The incision is then continued to the costal margin, or across the linea alba and left rectus, as desired. Two or three spurting arteries may need ligation near the posterior surface of the rectus muscle. Another artery requiring ligation runs in the falciform ligament of the liver which is usually severed whenever the incision extends beyond the midline.

The exposure of the organs mentioned will be found very satisfactory. After a few experiences the surgeon becomes convinced of a better exposure, an easier closure, and what is still more to be

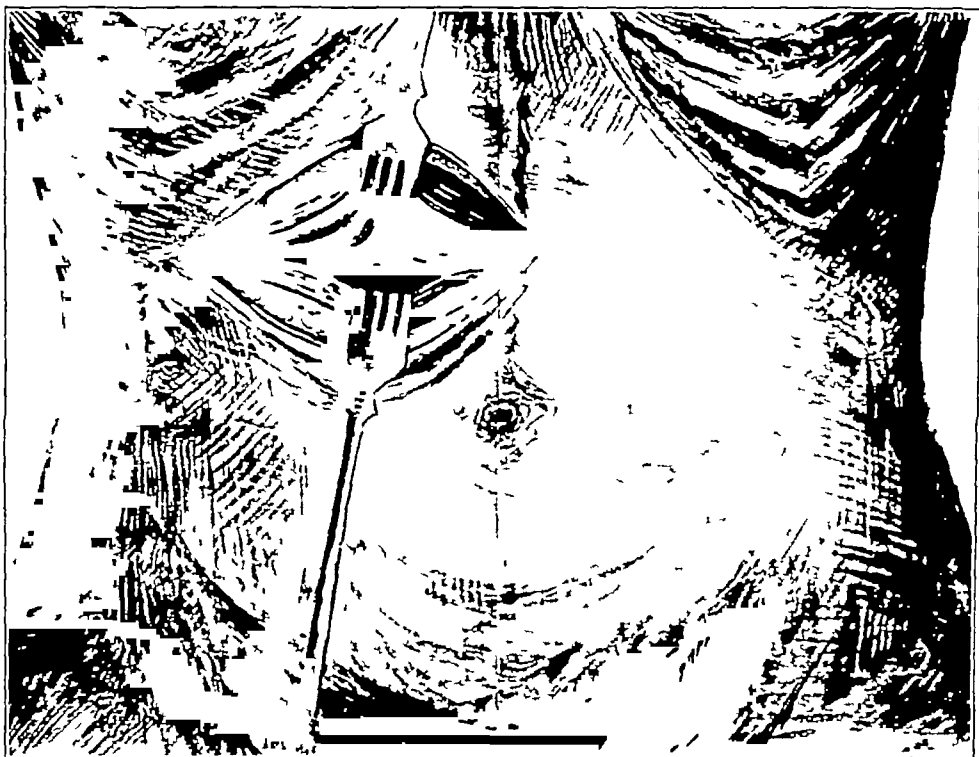


Fig 9—Transverse incision in epigastrium. Margin of liver and tip of gallbladder appearing in wound.

desired, he will learn that less harm has been done to the patient than by former methods.

Closure of the wound is accomplished by a running plain catgut suture of the posterior, and an interrupted, slightly overlapping, chromic catgut suture of the anterior aponeurosis. The cut ends of the recti may be approximated separately by a plain catgut suture if they seem to have retracted too far, but in most incisions they will be seen to come together very well from the interrupted suture of the external aponeurosis, the sutures being passed somewhat deeply into the muscle. An important point in the closure of this wound is the reconstruction

QUAIN—ABDOMINAL INCISIONS

of the linea alba This is best accomplished by a slight overlap, which overlap is reinforced by a silkworm suture in most of our operations (Figs 10 and 11)

In a previous article³ on "The Transverse Incision in the Upper Abdomen," my observations were based on slightly less than 300 operations by this method Since that time our experience has been increased by more than 200 additional transverse incisions, about 400

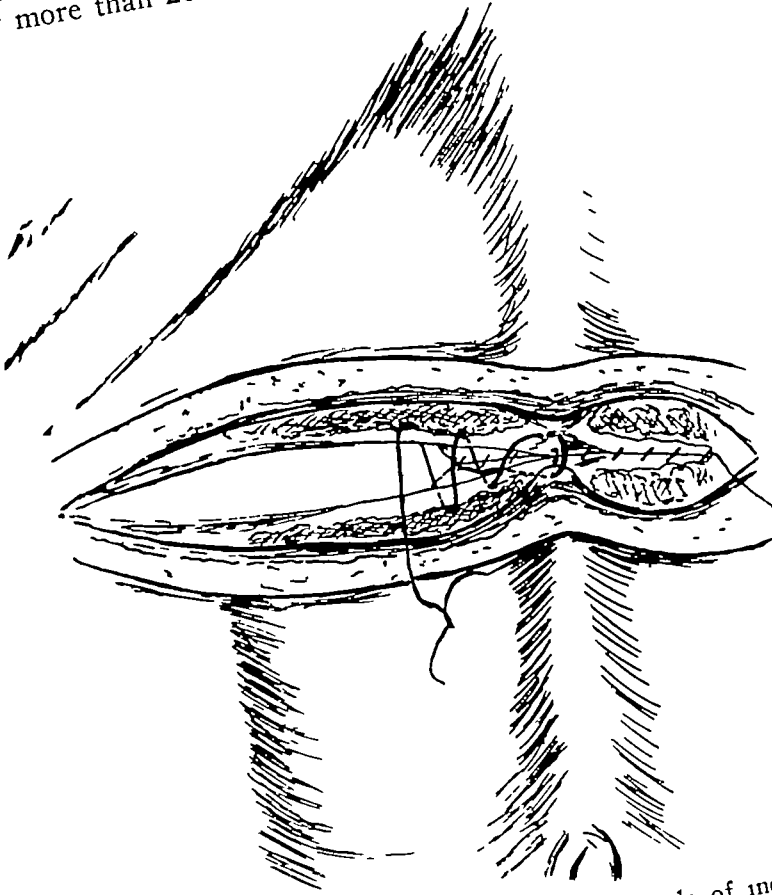


Fig 10—Closure of peritoneum beginning at left angle of incision, tied at linea alba, falciform ligament reconstructed and suture continued toward the right

of the total number being made because of a pathologic condition of the biliary tract and 100, in round numbers, for gastric lesions The favorable opinion expressed at that time both as to convenience of technic and after-results seems more than justified after this wider experience The comparative freedom from pain in the wound, the cosmetic appearance of the scar, and the absence of hernia have been

almost constant among our postoperative observations. One patient in whom an unusually extensive drainage had been employed because of a ruptured empyema of the gallbladder returned after two months with a distinct hernial bulge over the outer part of the rectus muscle. There seemed to be a defect in the deeper structures nearly an inch in diameter. Operation for its closure was advised, but the patient was unable to spare the time because of urgent farm work and agreed to return two months later. He did so and at that time it was found that the bulging had become distinctly smaller. Operation was again postponed two months for the purpose of studying the unusual behavior of this ventral hernia. When he returned at

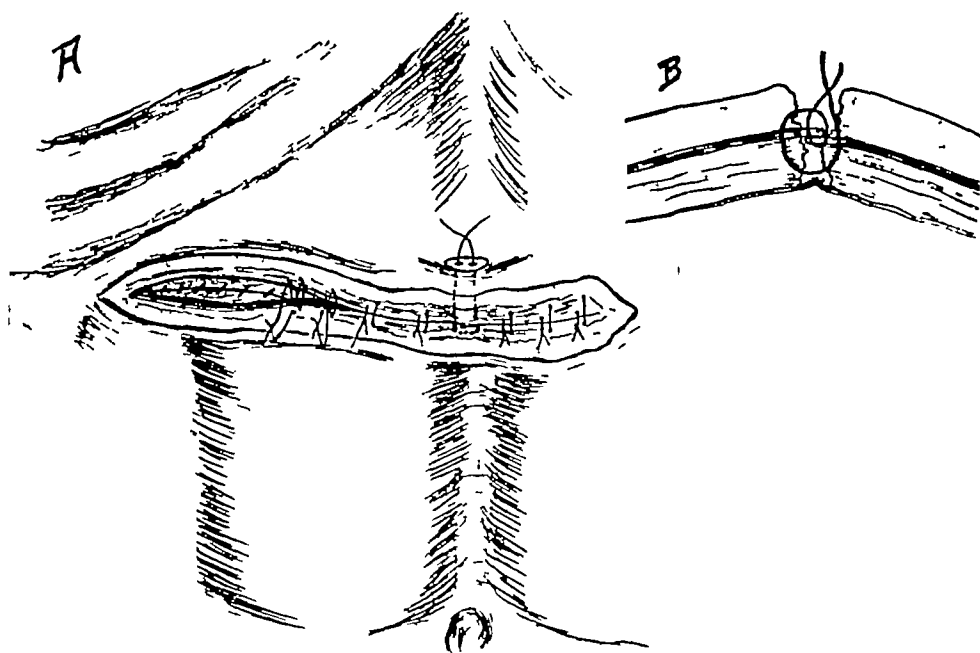


Fig 11—*A*, interrupted suture of rectus muscle and external aponeurosis, making the latter overlap. Silkworm gut suture through skin for fixation of linea alba. *B*, method of passing catgut through aponeurosis and rectus muscle.

the end of that time, there was no bulging at all. A spontaneous cure of an incisional hernia had taken place. One transverse wound burst open seven days after operation. This occurred in the case of a soldier on whom a cholecystectomy had been performed for empyema of the gallbladder in the presence of a severe bronchitis. The patient had a rather stormy recovery after operation because of the lung infection. The ward surgeon who had a standing instruction to remove all superficial stitches on the sixth day, because of his surgical inexperience, removed also the two silkworm gut fixation sutures on this day. The next day, in a severe fit of coughing, the wound suddenly gave way, and part of the omentum protruded. Immediate operation saved the patient's life.

From clinical experience, I have accumulated a large amount of evidence showing the harmful effects of lateral vertical incisions. During my service at a cantonment hospital, there were seventeen draft men operated on for hernia, pain, and adhesions in the scar after previous operations for appendicitis. In some of these, the appendix had been removed, in others, there had been only a simple drainage of an abscess. It was noted that in fifteen of the seventeen, either a straight right rectus incision had been made, or else an oblique incision with such an inclination downward along the semilunar line as to cut across the aponeurosis to some extent. Only two of the seventeen had had McBurney or split muscle incisions. In one of

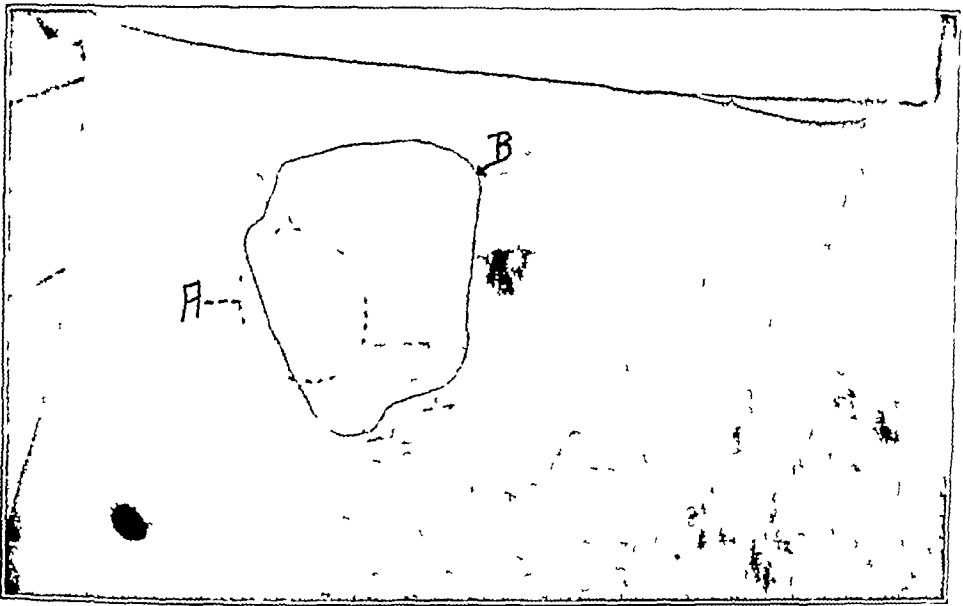


Fig 12—Patient with bulging and peritoneal adhesions after atypical right rectus incision (wound having healed primarily) *A*, outline of bulging due to defect in aponeurotic closure, *B*, outline of visceral adhesions to parietal peritoneum enervated by the incision

these, there were three separate small hernial sacs, with adherent omental tags between the transversalis fascia and muscles. In the other was found a loop of ileum firmly attached to the peritoneum and transversalis fascia. Since both had been clean cases, it is evident that they were both due to gross technical errors in the closure of the wounds, defective peritoneal suture in one, and catching of the bowel with one or more sutures in the other. Of the fifteen vertical incisions, two had healed primarily, but the hernia had appeared from heavy lifting, one and two years, respectively, after operation. It should be remembered that the base hospital received all defectives from a training camp which contained constantly from 40,000 to

70,000 recruits We cannot believe that the rectus incision had been employed eight times more frequently than the McBurney among the many recruits who had been operated on for appendicitis before being drafted If we should assume, in the absence of statistics on the subject, that the two incisions had been employed with equal frequency in the camp population, these figures would still indicate that the McBurney incision is more than eight times more satisfactory than the vertical

In the reconstruction hospital where I was on duty after the armistice, there were seven soldiers operated on for incisional hernia Two of these had followed appendectomies through pararectal incisions, one of which had been drained, while the other had been closed and healed primarily Two hernias had followed operations on the gallbladder through long transrectal incisions, and one of these two patients had already submitted to three unsuccessful operations for the hernia The other three hernias had followed atypical abdominal incisions for gunshot wounds of the abdomen All these cases gave especially beautiful demonstrations of the degenerating effect produced both on muscle and peritoneum by the destruction of the intercostal nerve supply The segment of the rectus muscle lying within the zone of the incision was atrophied and lifeless, and the peritoneum could not be distinguished because of firm adhesions (Fig 12)

A review of our operations in private practice for ventral or incisional hernia following laparotomies at the hands of other surgeons has furnished us with the same proof Nearly half of all such hernias have resulted from the type of incision denounced in this article In many of these the degeneration of muscle, fascia and peritoneum in the enervated segment of the abdomen has been easily demonstrable and sometimes irreparable

REVIEW OF CLINICAL HISTORIES

It is a rule in our practice that all patients who have had drainage after operations for suppurative appendicitis on leaving the hospital are informed that they may expect a hernia at the place of drainage They are further advised to return for examination and treatment as soon as any abnormal bulging appears at the site of incision It is conceded that data based solely on the number of patients who have returned for such secondary observations may not lead to entirely accurate conclusions as to the results following any given incision Yet our clientele is fairly constant, and it is believed that a review both of primary operations and secondary findings in a series of patients gives information of distinct value

Our review of clinical histories covers 347 consecutive cases of acute suppurative appendicitis, with localized or progressive peritonitis

Appendectomy was performed in nearly all, and drainage was established in every case. The tubes or cigaret drains ranged in number from one to ten. Patients who died after operation are not considered. In 287 of the 347, a split muscle, or McBurney incision, had been

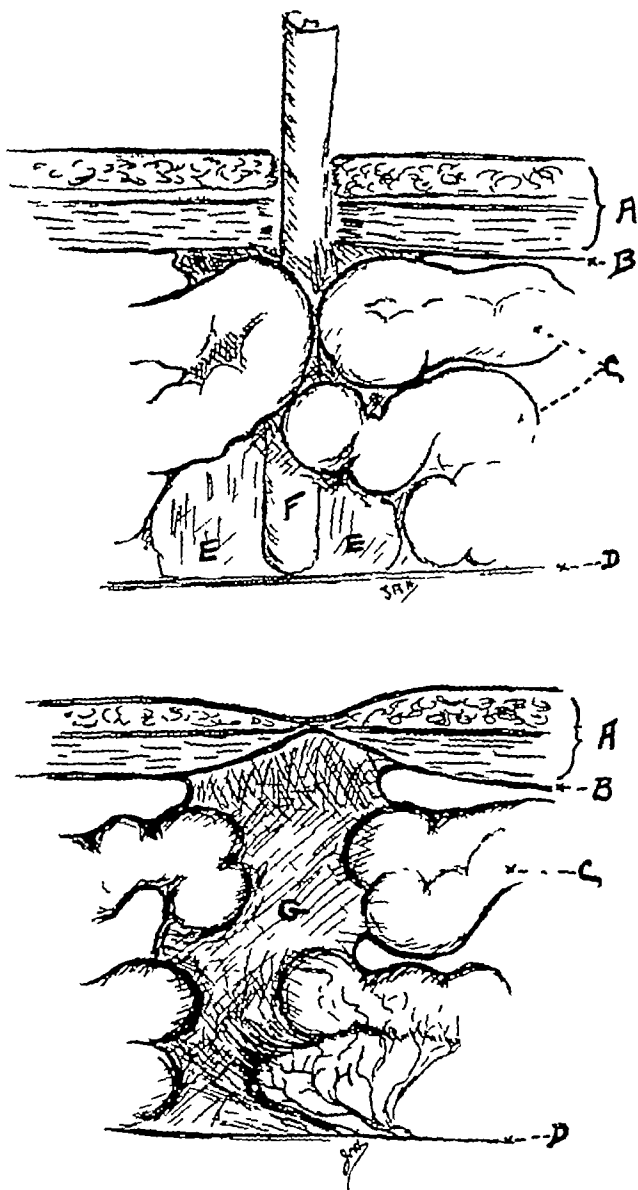


Fig 13—Result following drainage near center of abdomen. *A*, anterior abdominal wall, *B*, peritoneum, *C*, intestinal loops, *D*, posterior abdominal wall, *E*, abscess cavity, *F*, drainage material, *G*, postoperative adhesions, and *H*, mesentery.

used in the primary operation. This incision had been enlarged by cutting across the linea semilunaris in many instances. In a number of patients with extensive peritonitis there had been a second split

muscle incision for drainage above the left groin. Twenty-six, or 9 per cent of the 287, have returned for secondary operation for incisional hernia. In thirty-seven cases, the original split muscle incision had been found unsatisfactory at the primary operation, and it had therefore been enlarged by cutting across internal oblique and transversalis fibers, usually along the linea semilunaris, for from one-half to 2 inches. Nine of these, or nearly 25 per cent of the number, have returned for operation to close the resultant ventral hernia. In nineteen cases, mostly children, a median or paramedian incision had

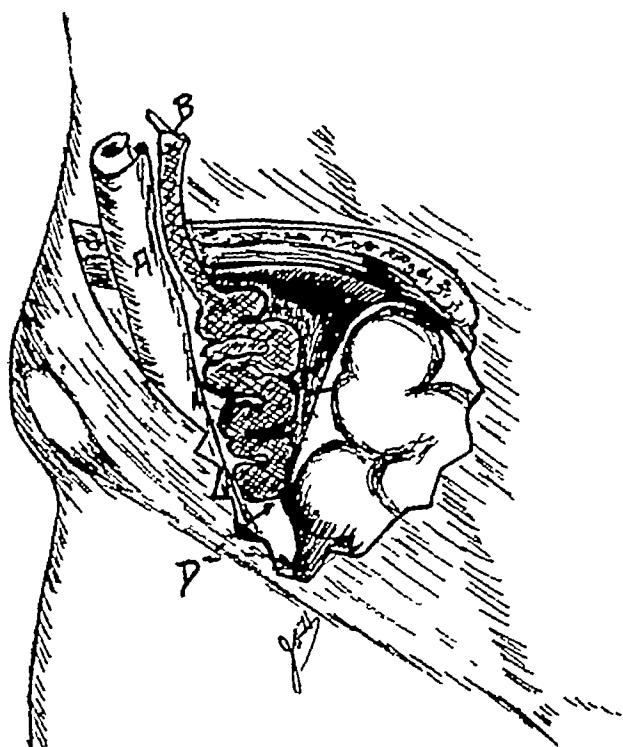


Fig 14—*A*, drainage near the groin and pushing of the peritoneum and transversalis fascia *C* by means of a gauze or rubber plug (*B*) help to shorten the intra-abdominal part of the drainage tract and thus to minimize the amount of postoperative adhesions *D*

been made, and of these six, or nearly one third, have returned for hernia operation. In four patients, the gridiron opening had been made too low, and a second splitting of the internal oblique and transversalis muscles had been made near the crest of the ilium through an extension outward of the same incision for the purpose of reaching and draining high infection. None of these have returned.

Another observation made in the secondary operations after appendiceal drainage has been the comparative ease of repair in those cases in which neither muscle nor nerve continuity had been damaged by destructive incision. The peritoneal adhesions are less extensive and

may be absent. The muscle fibers above and below the incision have, through functional activity, liberated themselves to an appreciable extent from the postoperative interfascicular infiltration. The muscle planes are readily found and restored. After primary vertical incision, the ends of the severed muscle fibers have retracted en masse and are often found embedded in a mat of cicatricial tissue, requiring much surgical skill and judgment in their successful dissection and resuturing. The intra-abdominal adhesions also are as a rule much more extensive and are less likely to be limited to the scar area, than they are when the previous incision has been more anatomically made.

The introduction of sutures to close partly an incision after the whole wound has become contaminated in the operation should be disapproved. Such suturing favors direct dissemination of infection into previously sterile tissues and invites further extension of infection and necrosis by restricting free circulation of blood and lymph. Experience has shown that the sutures often slough away, and the sloughing may involve fascial structures which the abdominal wall can ill afford to lose. If the incision, or incisions, be made parallel to the functional forces transmitted by the muscle bundles above and below the wound, the edges will tend to approach one another after the drainage tubes are removed. Later this secondary and imperfect union may of course be disrupted by the increasing intra-abdominal pressure due to early resumption of occupational activities, yet the experiences cited above go to show the comparative infrequency of this occurrence.

Operations for intra-abdominal infections usually include, and may be limited to, the establishment of drainage. Physical law and surgical experience both agree that liquids escape from a cavity most readily if it is opened at the bottom. This was one of the reasons which led to the establishment of low pelvic drainage and the sitting posture especially for infections in the lower half of the abdomen. The drainage may be established in the midline above the pubes, or still better, through an incision above one or both groins through a separation of the lateral muscle fibers. The establishment of any form of drainage is always followed by visceral adhesions at the place of drainage for a longer or shorter period. If the drainage is made some distance away from the lateral abdominal walls, these adhesions will *surround* the place of drainage and later form a fibrous band uniting the anterior to the posterior abdominal wall (Fig 13). The small intestines are frequently hampered in their free movements around this abnormal band of adhesions, and chronic pain or acute obstruction is not an uncommon result. By placing the drainage near the flank, groin or bladder so that one side of the drainage tract

is made up of normal and permanent abdominal wall, the amount of adhesions possible is reduced by nearly one-half. The margin of the peritoneum can be loosened slightly from the overlying muscles and pushed downward with a small pack so as to shorten materially the intra-abdominal part of the drainage tract and thus lessen further the amount of adhesions (Fig 14). From this technic there will be no postoperative band spanning the otherwise free abdominal cavity, and the patient will have less disability and less discomfort to remind him of his experience at the hands of the surgeon.

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